ARTIST'S CONCEPTION OF A VIKING

WONDER BOOK OF THE WORLD'S PROGRESS

By
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IN TEN VOLUMES
Illustrated

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VOLUME IV

Exploration
Animals

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EXPLORATION • ANIMAL LIFE

I

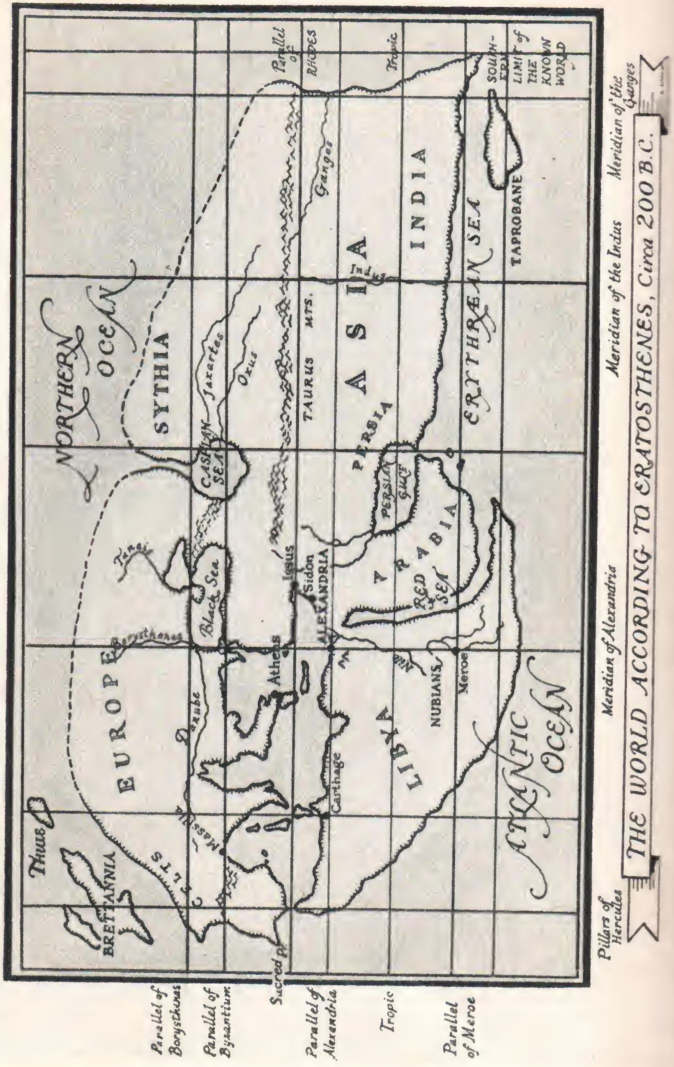
THE CONQUEST OF THE ZONES

THE contrast between modern and ancient times is strikingly suggested by reflection on the limited range of geographical knowledge of those Oriental and Classical nations who dominated the scene at that remote period which we are accustomed to characterize as the dawn of history.

The Egyptians, peopling the narrow valley of the Nile, scarcely had direct dealings with any people more remote than the Babylonians and Assyrians occupying the valley of the Euphrates. Babylonians and Assyrians in turn were in touch with no Eastern civilization more remote than that of Persia and India, and knew nothing of any Western world beyond the borders of Greece.

Greeks and Romans, when in succession they came to dominate the world stage — developing a civilization which even as viewed from our modern vantage-ground seems marvelous—were still confined to narrow strips of territory about the shores of the Mediterranean, and had but the vaguest notions as to any other regions of the earth.

In the later classical period, to be sure, the globe was subjected to wonderful measurements by Eratosthenes and by Posidonius, and the fact that man's abiding place is a great ball utterly different from the world as conceived by the Oriental mind was definitely grasped and became more or less a matter of common knowledge. It



THE WORLD ACCORDING TO ERATOSTHENES, Circa 200 B.C.

was even conceived that there might be a second habitable zone on the opposite side of the equator from the regions in which the Greeks and Romans found themselves, but as to just what this hypothetical region might be like, and as to what manner of beings might people it, even the most daring speculator made no attempt to decide. The more general view, indeed, precluded all thought of habitable regions lying beyond the confines of the Mediterranean civilization; conceiving rather that the world beyond was a mere waste of waters.

Doubtless the imaginative mind of the period must have chafed under these restrictions of geographical knowledge; and now and again a more daring navigator must have prest out beyond the limits of safety, into the Unknown, never to return. Once at least, even in the old Egyptian days, a band of navigators surpassing in daring all their predecessors, and their successors of the ensuing centuries, made bold to continue their explorations along the coast of Africa till they had passed to a region where —as Herodotus relates with wonder—the sun appeared "on their right hand," ultimately passing about the southern extremity of the African continent and completing the circumnavigation, returning with wonder tales to excite the envy, perhaps, but not the emulation of their fellows.

Then in due course some Phenician or Greek navigators coasted along the northern shores beyond the "Pillars of Hercules" and discovered at the very confines of the world what we now term the British Isles. But this was the full extent of exploration by the Mediterranean peoples throughout antiquity; and the spread of civilization about the borders of the known world was a slow and haphazard procedure during all those centuries that mark the Classical and Byzantine periods.

The change came with that revival of scientific learning which was to usher in the new era that we speak of as modern times. And here as always it was a practical mechanism that gave the stimulus to new endeavor. In this particular case the implement in question was the mariner's compass, which consists, in its essentials, as every one is aware, of a magnetized needle floated or suspended in such a way that it is made under the influence of terrestrial magnetism to point to the north and south.

The mysterious property whereby the magnetized needle obeys this inscrutable impulse is, in the last analysis, inexplicable even to the science of our day. But the facts, in their crude relations, had been familiar from time immemorial to a nation whose habitat lay beyond the ken of the classical world—namely, the Chinese. It seems to be fairly established that navigators of that nation had used the magnetized needle, so arranged as to constitute a crude compass, from a period possibly antedating the Christian Era. To Western nations, however, the properties in the magnetized needle seem to have been quite unknown—at least its possibilities of practical aid to the navigator were utterly unsuspected—until well into the Middle Ages. There is every reason to believe—tho absolute proof is lacking—that a knowledge of the compass came to the Western world from the Far East through the medium of the Arabs. The exact channel of this communication will perhaps always remain unknown. Nor have we any clear knowledge as to the exact time when the all-important information was transmitted. We only know that manuscripts of the twelfth century mentioned the magnetic needle as an implement familiar to navigators, and from this time forward, we may feel sure, the new possibilities of explora-

tion made possible by the compass must have suggested themselves to some at least of the more imaginative minds of each generation. Indeed, there were explorers in each generation who pushed out a little into the unknown, as the discovery of various groups of islands in the Atlantic shows, altho the efforts of these pioneers have been eclipsed by the spectacular feat of Columbus.

The exact steps by which the crude compass of the Orientals was developed into the more elaborate and delicate instrument familiar to Western navigators can not be traced by the modern historian. It is known that sundry experiments were made as to the best form of needle, and in particular as to the best way of adjusting it on approximately frictionless bearings. But a high degree of perfection in this regard had been attained before the modern period; and the compass had been further perfected by attaching the needle to a circumferential card on which the "points of the compass," thirty-two in number, were permanently marked. At all events the compass card had been so divided before the close of the fourteenth century, as is proved by a chance reference by Chaucer. The utility of the instrument thus perfected — indeed its entire indispensableness — was doubtless by this time clearly recognized by all navigators; and one risks nothing in suggesting that without the compass no such hazardous voyage into the unknown as that of Columbus would ever have been attempted.

No doubt the earliest observers of the needle believed that it pointed directly to the north. If such were indeed the fact the entire science of navigation would be vastly simpler than it is. But it required no very acute powers of observation to discover that the magnetized needle does not in reality point directly toward the earth's poles. There are indeed places on the earth where it does

ASTROLABE AND COMPASS

point, but in general it is observed to deviate by a few degrees from the exact line of the meridian. Such deviation is technically known as magnetic declination. That this declination is not the same for all places was discovered by Columbus on his first voyage.

A century or so later, the accumulated records made it clear that declination is not a fixt quantity even at any given place. An Englishman, Stephen Burrows, is credited with making the discovery that the needle thus shifts its direction slightly with the lapse of time, and the matter was more clearly determined a little later by Gellibrand, Professor of Geometry at Graham College. Dr. Halley, the celebrated astronomer—whose achievements have been recalled to succeeding generations by the periodical return of the comet that bears his name—gave the matter attention, and in a paper before the Royal Society in 1692 he pointed out that the direction of the needle at London had changed in a little over a century (between 1580 and 1692) from 11 degrees 15 minutes east to 6 degrees west, or more than 17 degrees.

Halley conclusively showed that similar variations occurred at all other places where records had been kept. He had already demonstrated, a few years earlier, that the deviations of the compass noted at sea are not due to the varying attractions of neighboring bodies of land, but to some influence having to do with the problem of terrestrial magnetism in its larger aspects. Halley advocated the doctrine, which had first been put forward by William Gilbert, that the earth itself is a gigantic magnet, and that the action of the compass is dependent upon this terrestrial source and not, as many navigators believed, on the influence of a magnetic star, or on localized deposits of lodestone somewhere in the unknown regions of the north.

ENGLISH LANDING AT ROANOKE

CAPTAIN SMITH'S SHIPS DESTROYED BY SPANIARDS

Further observations of the records presently made it clear that there are also annual and even daily variations of the compass of slight degree. The fact of diurnal variations was first discovered by Mr. Graham about the year 1719. More than half a century later it was observed by an astronomer named Wales, who was accompanying Captain Cook on his famous voyage around the world (1772-74), that there is yet another fluctuation of the compass due to the influence of the ship on which it is placed. Considerable quantities of iron were of course used in the construction of wooden ships, and it was made clear that the ship itself comes under the influence of the earth's magnetism and exerts in turn an appreciable influence on the compass. The fluctuation due to this source is known as deviation, in contradistinction to the larger fluctuation already referred to as declination.

Not only is the deviation due to the ship's influence a matter of importance, but it was discovered by Captain Matthew Flinders, in the course of his explorations along the coast of New Holland in the year 1801-02, that the influence of the ship over its compass varies with the direction of the ship's prow.

Needless to say, the problem of the deviation of the compass due to the influence of the ship is enormously complicated when the ship, instead of being constructed chiefly of wood, is made of iron or steel. It then becomes absolutely essential that the influence of vessels shall be reckoned with and so far as possible compensated. Such compensation may be effected by the adjustment of masses of iron, as first suggested by Barlow, or by the use of permanent magnets, as first attempted by England's Astronomer Royal, Professor Airy. At the very best, however, it is never possible totally to overcome

LANDING NEGROES AT JAMESTOWN, 1619

the ship's perverting influence, allowance for which must be made if an absolutely accurate conclusion is to be drawn from the record presented by the compass.

Early in the twentieth century an American ship, christened the *Carnegie*, in honor of the philanthropist who supplied funds for the enterprise, was constructed for the express purpose of making accurate charts of the lines of magnetic declination in various parts of the globe. This ship differs from every other vessel of considerable size ever hitherto constructed in that no magnetic material of any kind was used in connection with its structure or equipment. For the most part iron was substituted by copper or other non-magnetic metal. Pins of locust-wood largely took the place of nails; and wherever it was not feasible to do away with iron altogether it was used in the form of non-magnetic manganese steel. The purpose of the *Carnegie* is to provide accurate charts of magnetic declination for the use of navigators in general. The value of observations made with this non-magnetic ship will be clear when it is reflected that with an ordinary ship the observer can never be absolutely certain as to what precise share of the observed fluctuation of the compass is due at any given moment to the ship's influence. In other words—using technical terminology—he can never apportion with absolute accuracy the influence of declination and of deviation. Yet it is highly important that he should be able to do so, inasmuch as the declination of the compass is an all-important element in reckoning the exact location of the ship, and would be the same for every ship at that place, whereas deviation denotes a purely local disturbance which would never be the same for any two ships of different construction.

Not only does the magnetized needle thus tend to

CAPTAIN SCOTT'S SHIP TERRA NOVA
"FARTHEST SOUTH"

vary in the direction of its horizontal action, but it also tends when suspended at the middle to shift its vertical axis. In regions near the equator, indeed, the magnetized needle maintains a horizontal position, but if carried into northern or southern latitudes it progressively "dips," its polar end sinking lower and lower. This dipping of the needle seems to have been first observed by Robert Norman, an English nautical instrument maker about the year 1590. It was brought to the attention of Gilbert and carefully tested by him in the course of his famous pioneer experiments. Gilbert was led to predicate the existence of magnetic poles, the exact location of which would be indicated by the dipping needle, which, sinking lower and lower as northern latitudes were attained, would ultimately at the magnetic pole itself assume a vertical direction.

That this is a correct expression of the facts was determined in the year 1831 by Sir James Ross, who in the course of his Arctic explorations observed the vertical dip and so located the northern magnetic pole at about 70 degrees 5 minutes north latitude and 96 degrees 46 minutes west longitude. It was thus proved that the magnetic pole is situated a long distance—more than 1,200 miles—from the geographical pole. The location of the south magnetic pole was most accurately determined in 1909 by Lieutenant Shackleton's expedition at about 73 degrees south latitude and 156 degrees east longitude. The two magnetic poles are thus not directly opposite each other on the earth's surface, and the magnetic axis of the earth does not coincide with the geographical center of the globe itself.

From the standpoint of practical navigation the dip of the needle is a matter of much less significance than its horizontal fluctuations. Robert Norman himself at-

tempted to overcome the dip by a balancing apparatus applied to the needle; and the modern compass is suspended in such a way that the propensity to dip does not interfere with the lateral movements which supply the navigator with all important information. The modern compass in question is the invention of Lord Kelvin and was patented by him in 1876. It consists of a number of small magnets arranged in parallel and held in position by silk threads, each suspended, cobweb-like, from the circular rim of aluminum. The weight—which in the aggregate is relatively slight—being thus largely at the circumference, the instrument has a maximum period of oscillation and hence a high degree of stability. Its fluctuations due to the ship's influence are corrected by a carefully adjusted disposition of metal balls and magnets.

While the compass gives indispensable information as to direction, and is constantly under the eye of the pilot, it of course can give no direct information as to the distance traversed by the ship, and hence does not by itself suffice to tell the navigator his whereabouts. In the early days there was indeed an expectation that the observed declination of the compass would reveal to the navigator his longitude and that the observation of the dip might enable him to determine his latitude. But more extended observation shows that this was asking altogether too much of the compass, and while it may be useful as an accessory it is by no means the navigator's chief reliance in determining his location. This is accomplished, as every one is aware, in clear weather by the observation of the heavenly bodies. In cloudy weather, however, such observations obviously can not be made, and the seaman must direct his ship and estimate his location—an all-important matter when he is

approaching the coast—by what is called dead reckoning. One element of this reckoning is furnished by the compass, inasmuch as that is his sole guide in determining the direction of the ship's progress. The other element is supplied by the log which furnishes him a clue as to the distance traversed hour by hour.

It is rather startling to reflect that the navigators of the Middle Ages had no means whatever of determining the rate of progress of a ship at sea, beyond the crudest guesses unaided by instruments of any kind. When Columbus made his voyage he had no means of knowing what distance he had actually sailed; nor was any method of measuring the ship's speed utilized throughout the course of the ensuing century. In the year 1570, however, one Humfray Cole suggested a theoretical means of measuring the ship's rate of progress by means of an object dropt back of the ship and allowed to drag through the water; and this suggestion led a generation later to the introduction of the log, which was first actually used, so far as can be learned, in the year 1607.

The original log was so called because it consisted essentially of an actual log or piece of wood. To the center of this a string was attached, and in testing the ship's rate of progress this string was allowed to slip through the fingers of a sailor who counted the number of knots—placed, of course, at regular intervals on the string—that passed through his fingers in a given time. As the log itself would remain practically stationary in the water where it was dropt, the number of knots counted indicated the distances traversed by the ship in a given time. In practise the time was usually gaged by a half-minute sand-glass, and the knots were arranged at such a distance on the cord that, in the course of the half-minute, one knot would pass through the fingers

ADMIRAL BYRD: NORTH POLE AIRPLANE

USING SEXTANT

for each nautical mile covered by the ship in an hour. The actual distance between the knots was therefore about fifty feet. The nautical or geographical mile represents one degree of the earth's circumference at the equator, amounting therefore to 6,008 feet, as against the 5,280 feet of the statute mile. It was the use of the log-line with its knots, as just explained, that led to the defining of the nautical mile by the name "knot," which is still familiarly employed, tho the knotted log-line itself has been superseded in recent times, except on very old-fashioned sailing ships.

The log retains its place even in the most modern ship, tho its form is materially altered, and its importance is somewhat lessened owing to the fact that the experienced skipper can test the speed of his ship very accurately by noting the number of revolutions per minute of the ship's propellers. It is indeed the ship's propeller that supplies the model for the modern log, in which the primitive piece of wood is replaced by a torpedo-like piece of metal with miniature propeller-like blades at its extremity. This apparatus is towed at the end of a long line, and its blades, whirling more or less rapidly according to the speed of the ship, communicate their motion to a recording apparatus, adjusted at the ship's stern, to which the line is attached and the face of which ordinarily presents a dial on which the speed of the ship may be observed as readily as one observes the time by the clock.

Some recent modifications of the log employ an electrical device to register the progress, but the principle of the revolving vanes, which owe their speed to the rate at which they are dragged through the water, is the fundamental one upon which the action of the log usually depends.

While the modern log records the speed of the ship with a fair degree of accuracy, its register shows at best only an approximation of the facts. As already mentioned the rate of revolution of the ship's propeller blades furnishes what most navigators regard as a rather more dependable test of speed. An apparatus for recording this is found on the bridge of the modern ship. But due allowance must of course be made for the effect of winds, waves, and ocean currents. These constantly variable factors obviously make the estimate as to the precise distance traversed by a ship in a given time a matter not altogether devoid of guesswork; and no navigator who has been obliged to sail for several days by dead reckoning approaches a coast with quite the same degree of satisfaction that he may entertain if his log has been checked by observation of the sun or stars. In case, however, a navigator is able to check his reckoning by astronomical observations, aided by the chronometer, he determines his location with great accuracy.

The instrument with which such astronomical observations are made is known as the sextant. Its purpose is to measure with great accuracy the angle between two objects, which in practise are the horizon line on one hand and some celestial body, usually the sun, on the other. The determination of the latitude of the ship, for example, is a matter of comparative ease, if the sun chances to be unobscured just at midday. The navigator has merely to measure the exact elevation of the sun as it crosses the meridian—that is to say, when it is at its highest point—and, having made certain corrections for so-called dip and refraction, to which we shall refer more at length in a moment, a very simple calculation reveals the latitude—that is to say, the distance from the terrestrial equator.

That the latitude of a ship could thus be determined, with greater or less accuracy, has been familiar knowledge to seamen from a very early period. It was by the use of this principle that the earth was measured by Eratosthenes and Posidonius in classical times and the sailors of antiquity probably carried with them a crude apparatus for measuring the height of sun and stars, as the medieval navigators are known to have done.

The simplest and crudest form of measurer of which any record has been preserved is known as the cross-staff. This consisted essentially of a stick about a yard in length called the staff, on which a crosspiece was arranged at right angles, so adjusted at the center as to slide back and forth on the staff. An eyepiece at one end of the staff was utilized to sight along projections at either end of the crosspiece. If the apparatus is held so that one of the lines of sight is directed to the horizon, and then the crosspiece slid along the staff until the other line of sight is directed toward the sun or a given star, the angle between the two lines of sight will obviously represent the angle of altitude of the celestial body in question. But the difficulty of using an apparatus which requires two successive observations to be made without shift of position is obvious, and it is clear that the information derived from the cross-staff must have been at best very vague—by no means such as would satisfy the modern navigator.

Even the navigators of the fifteenth century were aware of the deficiencies of the cross-staff and sought to improve upon it. The physicians of Henry the Navigator of Portugal, Roderick and Joseph by name, and another of his advisers, Martin de Bohemia, are credited with inventing, or at least introducing, a much improved apparatus known as the astrolabe. This con-

HENRY HUDSON AT NEW AMSTERDAM

sists of a circle of metal, arranged to be suspended from a ring at the side, so that one of its diameters would maintain the horizontal position through the effect of gravity. A superior quadrant of the circle was marked with degrees and minutes. A straight piece of metal, with sights so that it could be accurately pointed, was adjusted to revolve on a pivot at the center of the circle. This sighting piece being aimed at the sun, for example, the elevation of that body could be read directly on the measuring arc of the circle. Here, then, was no new principle involved, but the instrument had obvious points of advantage over the cross-staff, in particular because only a single sight need be taken, the horizon line being determined, as already explained, through the action of gravitation.

The astrolabe did not gain immediate favor with practical navigators, and it was at best a rather clumsy instrument, subject to peculiar difficulties when used on a rolling ship. Many attempts were made to improve upon it, but for a long time none of these was altogether successful. The final suggestion as to means of overcoming the difficulties encountered in measuring the altitude of astronomical bodies was made by Sir Isaac Newton. But nothing practical came of his discovery, as it was not published until a long time after his death. Meantime independent discovery of the same principle was made by Thomas Godfrey, of Philadelphia, in 1730, and by the English astronomer, Hadley, who published his discovery before the Royal Society in 1731. The instrument which Hadley devised was called a quadrant. The principle on which it worked involved nothing more complex than the use of two mirrors, one of them (known as the horizon glass and having only half its surface mirrored) fixt in the line of vision of a small

telescope; the other (called the index mirror) movable with the arm of an indicator, which is so adjusted as to revolve about the axis of the quadrant. In operation these two mirrors enable the images of two objects, the distance between which is to be measured, to be superimposed. The telescope may be pointed at the horizon, for example, directly under the position of the sun, and the arm of the instrument, altering the position of the so-called index mirror, may be rotated until the limb of the sun seems just to touch the horizon—the latter being viewed through the unsilvered half of the horizon glass. The scale at the circumference of the instrument is marked in half-degrees, which, however, are registered as whole degrees, and which, so interpreted, give the direct measurement of the angular distance between the horizon and the sun; in other words, the measurement of the sun's altitude or so-called declination.

The instrument just described, perfected as to details but not modified as to principles, constitutes the modern sextant, which is used by every navigator, and which constitutes, along with the compass and chronometer, the practical instrumental equipment that enables the seaman to determine—by using the tables of the *Nautical Almanac*—his exact position on the earth's surface from observation of the sun or certain of the fixt stars. The modern instrument is called a sextant because it has, for convenience' sake, been restricted in size to about one-sixth of a circle instead of the original one-quarter, the small size being found to answer every practical purpose, since it measures all angles up to 120 degrees.

In practise the sextant is an instrument only six or eight inches in diameter. It is held in the right hand and the movable radial arm is adjusted with the left

hand with the aid of a micrometer screw and the reading of the scale is made accurate by the vernier arrangement. The ordinary observation—which every traveler has seen a navigator make from the ship's bridge just at midday—is carried out by holding the sextant in a vertical position directly in line of the sun, and sighting the visible horizon line, meantime adjusting the recording apparatus so as to keep the sun's limb seemingly in touch with the horizon. As the sun is constantly shifting its position the vernier must be constantly adjusted until the observation shows that the sun is at the very highest point. The instrument being clamped and the scale read, the latitude may be known when proper correction has been made for the so-called dip, for refraction, and where great accuracy is required, for parallax.

Dip, it may be explained, is due to the fact that the observation is made not from the surface of the water but from an elevation, which is greater or less according to the height of the bridge, and which therefore varies with each individual ship. The error of refraction is due to the refraction of the sun's light in passing through the earth's atmosphere, and will vary with the temperature and the degree of atmospheric humidity, both of which conditions must be taken into account. The amount of refractive error is very great if an object lies near the horizon. Every one is familiar with the oval appearance of the rising or setting sun, which is due to refraction. With the sun at the meridian, the refractive error is comparatively slight; and when a star is observed at the zenith the refractive error disappears altogether.

By parallax, as here employed, is meant the error due to the difference in the apparent position of the sun as viewed by an observer at any point of the earth's sur-

ESKIMO VISITORS — ADMIRAL PEARY

ence from what the apparent position would be if viewed from the line of the center of the earth, from which theoretical point the observations are supposed to be made. In the case of bodies so distant as the sun, this angle is an exceedingly minute one, and in the case of the fixed stars it disappears altogether. The sun's parallax is very material indeed from the standpoint of delicate astronomical observations, but it may be ignored altogether by the practical navigator in all ordinary observations. There is one other correction that he must make, however, in case of sun observations; he must add, namely, the amount of the semi-diameter of the sun to the observed measurement, as all calculations recorded in the *Nautical Almanac* refer to the center of the sun's disk.

The observation of the sun's height, with the various corrections just suggested, suffices by itself to define the latitude of the observer. Something more is required, however, before he can know his longitude. How to determine this, was a problem that long taxed the ingenuity of the astronomer. The solution came finally through the invention of the chronometer, which is in effect an exceedingly accurate watch.

Time measurers of various types have, of course, been employed from the earliest times. The ancient Oriental and Classical nations employed the so-called clepsydra, which consisted essentially of receptacles from or into which water dript through a small aperture, the lapse of time being measured by the quantity of water. At an undetermined later date sand was substituted for the water, and the hour-glass with which, in some of its forms, nearly every one is familiar, came into use. For a long time this remained the most accurate of time measurers, tho efforts were early made to find substitutes

of greater convenience. Then clocks operated by weights and pulleys were introduced; and, finally, after the time of the Dutchman Huygens, the pendulum-clock furnished a timepiece of great reliability. But the mechanism operated by weight or pendulum is obviously ill-adapted to use on shipboard. Portable watches, in which coiled springs took the place of the pendulum, had indeed been introduced, but the mechanical ingenuity of the watchmaker could not suffice to produce very dependable timekeepers. The very idea of a watch that would keep time accurately enough to be depended upon for astronomical observations intended to determine longitude was considered chimerical.

Nevertheless the desirability of producing a portable timekeeper of great accuracy was obvious, and the efforts of a large number of experimenters were directed toward this end in the course of the eighteenth century. These efforts were stimulated by the hope of earning a prize of twenty thousand pounds offered by the British Government for a watch sufficiently accurate to determine the location of a ship with maximum error of half a degree or thirty nautical miles, corresponding to two minutes of time, in the course of a transatlantic voyage. It affords a striking illustration of the relative backwardness of nautical science, and of the difficulties to be overcome, to reflect that no means then available enabled the navigator at the termination of a transatlantic voyage to be sure of his location within the distance of thirty nautical miles by any means of astronomical or other observation known to the science of the time.

The problem was finally solved by an ingenious British carpenter named John Harrison, who devoted his life to the undertaking, and who came finally to be the most successful of watchmakers. Harrison first achieved

distinction by inventing the compensating pendulum—a pendulum made of two metals having a different rate of expansion under the influence of heat, so adjusted that change in one was compensated by a different rate of change in the other. Up to the time of this discovery, even the best of pendulum clocks had failed of an ideal degree of accuracy owing to the liability to change of length of the pendulum—and so, of course, to corresponding change in the rate of its oscillation—with every alteration of temperature. Another means of effecting the desired compensation was subsequently devised by Mr. Graham, through the use of a well of mercury in connection with the pendulum, so arranged that the expansion of the mercury upward in its tube would compensate the lengthening of the pendulum itself under effect of heat, and vice versa; but the Harrison pendulum, variously modified in design, remains in use as a highly satisfactory solution of the problem.

Harrison early conceived the idea that it might be possible to apply the same principle to the balance-wheel of the watch. This problem presented very great practical difficulties, but by persistent effort these were finally overcome, and a balance-wheel produced, which, owing to the unequal expansion and contraction of its two component metals under changing temperature, altered its shape and so maintained its rate of oscillation almost—tho never quite—regardless of changing conditions of temperature.

In 1761 Harrison produced a watch which was tested on a British ship in a trip to the West Indies in that and the succeeding year, and which proved to be a timekeeper of hitherto unexampled accuracy. The inventor had calculated that the watch, when carried into the tropics, would vary its speed by one second per day

ROALD AMUNDSEN'S *NORGE* AND *FRAM*

with each average rise of ten degrees of temperature. Making allowance for this predicted alteration it was found that the watch was far within the limits of variation allowed by the conditions of the test above outlined. It had varied indeed only five seconds during the journey across the ocean. On the return trip the watch was kept in a place near the stern of the ship, for the sake of dryness, where, however, it was subjected to a great deal of joggling, which led to a considerably greater irregularity of action; but even so its variation on reaching British shores was such as to cause a maximum miscalculation of considerably less than thirty nautical miles.

Altho Harrison seemed clearly enough to have won the prize, there were influences at work that interfered for a time with full recognition of his accomplishment. Presently he received half the sum, however, and ultimately, after having divulged the secret of his compensating balance and proved that he could make other watches of corresponding accuracy, he received the full award.

Minor improvements have naturally been made in the watch since that time, but the essential problem of making a really reliable portable timepiece was solved by the compensating balance-wheel of Harrison. The ship's chronometer of today is merely a large watch, with an escapement of particular construction, mounted on gimbals so that it will maintain a practically horizontal position.

Modern ships are ordinarily provided with at least three of these timekeepers in order that each may be compared with the others, and a more accurate determination of the time made than would be possible from observation of a single instrument; inasmuch as no

MIDNIGHT SUN PHOTOGRAPHED BY DR. COOK

absolutely accurate timekeeper has ever been constructed. Two chronometers would obviously be not much better than one, since there would be no guide as to whether any variation between them had been caused by one running too fast or the other too slowly. But with a third chronometer to check the comparison, it is equally obvious that a dependable clue will be given as to the exact time.

It is to be understood of course that the variation of any of the chronometers will be but slight if they are good instruments. Moreover the tendency to vary in one direction or the other of each individual instrument will be known from previous tests. Such tests are constantly made at the Royal Observatory in England and elsewhere, and the best chronometers bear certificates as to their accuracy and as to their rate of variation. It may be added that a chronometer or other timepiece is technically said to be a perfect instrument, not when it has no variation at all—since this has proved an unattainable ideal — but when its variation is slight, is always in one direction, and is perfectly or almost perfectly uniform.

In the reference made above to the testing of Harrison's watch, it was stated that that instrument varied by only a certain number of seconds in the course of the westerly voyage across the Atlantic, and that its variation was somewhat greater on the return voyage. This implies, clearly, that some method was available to test the watch in the West Indies, without waiting for the return to England. At first thought this may cause no surprise, since the local time can of course be known anywhere through meridian observations; but on reflection it may seem less and less obvious as to just what test was available through which the exact difference

WILLIAM PENN MAKES A TREATY

in time between Greenwich, at which the watch was originally tested, and local time at the station in the West Indies could be determined. There are, however, several astronomical observations through which this could be accomplished, and in point of fact the comparative times and hence the precise longitudes at many points on the Western Hemisphere—and indeed of all portions of the civilized globe—were accurately known before the day of the chronometer.

One of the simplest and most direct means of testing the time of a place, as compared with Greenwich time, is furnished by observation of the occultation of one of the moons of Jupiter. By occultation is meant, as is well known, the eclipse of the body through passing into the shadow of its parent planet. This phenomenon, causing the sudden blotting out of the satellite as viewed from the earth, occurs at definite and calculable periods and is obviously quite independent of any terrestrial influence. It occurs at a given instant of time and would be observed at that instant by any mundane witness to whom Jupiter was at that time visible. If then an observer noted the exact local time at which occultation occurred, and compared this observed time with the Greenwich time at which such occultation was predicted to occur, as recorded in astronomical tables, a simple subtraction or addition will tell him the difference in time between his station and the meridian at Greenwich; and this difference of time can be translated into degrees of longitude by merely reckoning fifteen degrees for each hour of time, and fractions of the hour in that proportion.

It will be noted that this observation has value for the purpose in question only in conjunction with certain tables in which the movements of Jupiter and its satellite are calculated in advance. This is equally true of the var-

AMUNDSEN A-WING AND A-SLEDGE

ious other observations through which the same information may be obtained—as for example, the observation of a transit of Mars, or the measurement of apparent distance between the moon and a given fixt star. Before the tables giving such computations were published it was quite impossible to determine the exact longitude of any transatlantic place whatsoever. We have already pointed out that Columbus had only a vague notion as to how far he had sailed when he discovered land in the West. The same vagueness obtained with all the explorations of the immediately ensuing generations.

It was not until about the middle of the sixteenth century that Mercator and his successors brought the art of map-making to perfection; and the celebrated astronomical tables of the German Mayer, which served as the foundation for calculations of great importance to the navigator, were not published until 1753. The first *Nautical Almanac*, in which astronomical tables to guide the navigator were included, was published at the British Royal Observatory in 1767.

At the present time, a navigator would be as likely to start on a voyage without compass and sextant as without charts and a *Nautical Almanac*. Indeed, were he to overlook the latter the former would serve but a vague and inadequate purpose. Yet, as just indicated, this invaluable adjunct to the equipment of the navigator was not available until well toward the close of the eighteenth century. But of course numerous general tables had been in use long before this, else—to revert to the matter directly in hand—it would not have been possible to make the above-recorded test in the case of Harrison's famous watch in the voyage of 1761-62.

Time was, when maps and charts were not to be had, and when in consequence the navigator who started on

ON COME THE VIKINGS

his voyages of exploration was undertaking a feat never free from hazard. Until the time of Mercator there was not even uniformity of method among map-makers in the charting of regions that had been explored. The thing seems simple enough now, thanks to the maps with which every one has been familiar since childhood. But it required no small exercise of ingenuity to devise a reasonably satisfactory method of representing on a flat surface regions that in reality are distributed over the surface of a globe.

The method devised by Mercator, and which, as every one knows, is now universally adopted, consists in drawing the meridians as parallel lines, giving therefore a most distorted presentation of the globe, in which the distance between the meridians at the poles—where in reality there is no distance at all—is precisely as great as at the equator. To make amends for this distortion, the parallels of latitude are not drawn equi-distant, as in reality they practically are on the globe, but are spaced farther and farther apart, as we advance from the equator toward either pole.

The net result is that an island in the arctic region would be represented on the map several times as large as an island actually the same size but located near the equator. Doubtless most of us habitually conceive Alaska and Greenland to be vastly more extensive regions than they really are, because of our familiarity with maps showing this so-called "Mercator's projection."

Of course, maps are also made that hold to the true proportions, representing the lines of latitude as equidistant and the meridians of longitude as lines converging to a point at the poles. But while such a map as this has certain advantages—giving, for example, a correct notion of the relative sizes of polar and other land masses

THE SANTA MARIA OF COLUMBUS

—it is otherwise confusing, inasmuch as places that really lie directly in the north and south line can not be so represented except just at the middle of the map, and it is very difficult for the ordinary user of the map to gain a clear notion as to the actual points of the compass.

A satisfactory compromise may be effected, however, by using Mercator's projection for maps showing wide areas, while the other method is employed for local maps.

VIKINGS LANDING

THE PILGRIMS AT PLYMOUTH

II

THE LURE OF THE UNKNOWN

WHILE the average man, even with well-developed traveling instincts, would perhaps prefer always to feel that he is sailing in well-charted waters and along carefully surveyed coasts, there have been in every generation men who delighted in taking risks, and for whom half the charm of a voyage must always lie in its dangers. Such men have been the pioneers in exploring the new regions of the globe.

That there was no dearth of such restless spirits in classical times and even in the Dark Ages, records that have come down to us sufficiently attest. For the most part, however, their names have not been preserved to us. But since the ushering-in of the period which we today think of as the beginning of modern times, records have been kept of all important voyages of discovery, and at least the main outlines of the story of the conquest of the zones are familiar to every one.

Some of the earliest explorers, most notable among whom was the Italian Marco Polo, traveled eastward from the Mediterranean and hence journeyed largely by land. But soon afterward, thanks to the introduction of the compass — which instrument Marco Polo has sometimes been mistakenly accredited with bringing from the East—the adventurers began to cast longing eyes out toward the western horizons.

Among the first conspicuous and inspiriting results were the discoveries of the groups of islands known as

PILGRIMS LANDING

LASALLE IN LOUISIANA

the Cape Verdes and the Azores. The Canary Islands were visited by Spaniards even earlier, and became the subject of controversy with the other chief maritime nation of the period, the Portuguese.

When the controversy was adjusted the Spaniards were left in possession of the Canaries, but the Portuguese were given by treaty the exclusive right to explore the coast of Africa. Following up sundry tentative efforts, the daring Portuguese navigator Bartholomeu Diaz, in the year 1487, passed to the southernmost extremity of Africa, which he christened the Cape of Good Hope. At last, then, it had been shown that Africa did not offer an interminable barrier to the passage to the fabled land of treasures in the East. Before any one had ventured to follow out the clues which the discovery of the Cape had presented, however, Columbus had seemingly solved the problem in another way by sailing out boldly into the West and supposedly coming to the East Indies in 1492.

Long before this, however, if tradition is to be credited, America had been discovered by the hardy sea rovers of the north. The modern tendency is to accept the authenticity of accounts given in the Norse *Sagas*, according to which the Northmen reached America by way of the stepping-stone of Iceland, into Greenland, and thence down the coast as far as a region where vines grew. It is claimed that the year after the first Norse settlers reached Iceland a Norseman called Gunnbjörn was driven west so far that he sighted a new land. Half a century later the Norse adventurers found Iceland the Great.

Next appears the Red Eric, a murderous brawler who left Norway for his country's good, and later found even Iceland too peaceful for him. Sent into three years' exile,

he went hunting a more congenial shore. Having heard of the land that Gunnbjörn had seen, he sailed due west and found it. Returning at the end of his term of banishment he desired to take out colonists. The Saga of Eric the Red credits him with shrewdness, for "he called the land which he had found Greenland, because, quoth he, 'people will be attracted thither if the land has a good name.' "

So effective were his stories of the arctic region, that in 985 (?) thirty-five ships set forth with him, of which twenty-one were lost on the way. This was the beginning of genuine colonization. In 999 Eric's son Leif went back to Norway and found that Christianity had become the state religion. He was converted and took back to Greenland a priest, the first Christian missionary to the western world.

This great and undoubted colonization of a portion of arctic Greenland was doomed to ultimate failure, and the colonies eventually disappeared. Some have said that the Eskimos began to drive the Northmen out as early as 1342. Communication with Iceland and the home country of Norway ceased entirely in the fifteenth century. All that remains of the colony now is a few ruins and a few doubtful remnants of custom or tradition among the Eskimos.

As early as 986, if we can believe the sagas, one Bjarni Herjulfson, set out from Iceland for Greenland; but was so beset by north winds and fogs that he lost his bearings and at last made out a coast which did not conform to Eric the Red's account of the mountainous and icy coast of Greenland. This land was "without mountains and covered with wood." They turned north and on their way they saw four different lands and finally reached Greenland, where Bjarni gave up seafaring. Such is the simple detail of the first voyage of the Northmen to the western hemisphere.

Rafn felt that there were sufficient data in the ancient Icelandic geographical works to determine the position of the various coasts and headlands thus discovered by Bjarni Herjulfson. A day's sail was estimated by the Northmen from twenty-seven to thirty geographical miles, and the knowledge of this fact, together with that of the direction of the wind, the course steered, the appearance of the shores, and other details contained in the narrative itself, together with the more minute description of the same lands given by succeeding voyagers, has convinced some historians that the countries thus discovered by Bjarni Herjulfson were Connecticut, Long Island, Rhode Island, Massachusetts, Nova Scotia, and Newfoundland; and that the date of the expedition is determined by the passage in the preliminary narrative which fixes the period of Herjulfson's settlement at Herjulf's Ness in Iceland. R. G. Haliburton gives a map in which Bjarni's course is marked as entering the St. Lawrence Gulf by the south, and emerging by the straits of Belle Isle.

It may, perhaps, be urged in disparagement of these discoveries that they were accidental—that Bjarni Herjulfson set out in search of Greenland, and fell in with the eastern coast of North America; but so it was, also, with Columbus.

Bjarni had had enough of the North Atlantic winds, but the story excited Leif, Eric's son, to hunt that fair shore seen by Bjarni. About the year 1000 he set out with thirty-five companions. According to the detailed story preserved in the *Sagas*, this voyage resulted in the visiting of America as far south as Nantucket Island, and the ultimate founding of a colony in what came to

COLUMBUS AT COURT

ANNEXING AMERICA

be spoken of as Vinland the Good. It would even appear that the colony flourished and was promoted by a third son of Eric the Red, named Thorfinn, whose first voyage to the colony was made in the year 1007.

In the year 1011, the colony in Vinland left by Thorfinn was joined by Helge and Finnboge, two brothers from Iceland, who were accompanied in their voyage by Thorwald and his wife Freydisa, a daughter of Eric the Red. This woman excited a quarrel, which proved fatal to about thirty of the colonists. Detested for her vices, she was constrained to return to Greenland, where she lived despised and died unlamented.

From this period we hear no more of the northern colony in America till the year 1059, when an Irish or Saxon priest, named Jon or John, who had preached some time as a missionary in Iceland, went to Vinland for the purpose of converting the colonists to Christianity and was murdered there by the heathen. A bishop of Greenland, Erik Upsa, afterwards (1121) undertook the same votage for the same purpose, but his success is uncertain.

The authenticity of the Icelandic accounts of the discovery and settlement of Vinland was recognized in Denmark, shortly after this period, by King Sweyn Estrithson, Sweno II, in a conversation which Adam of Bremen had with this monarch.

In the latter part of the fourteenth century, two Venetian navigators, sailing in the service of a Norman prince of the Orcades, are said to have visited Vinland, and to have found traces of the colony left by the Northmen. From that time to the discovery of the New World by Columbus, there was no communication—none at least that is known—between it and the north of Europe.

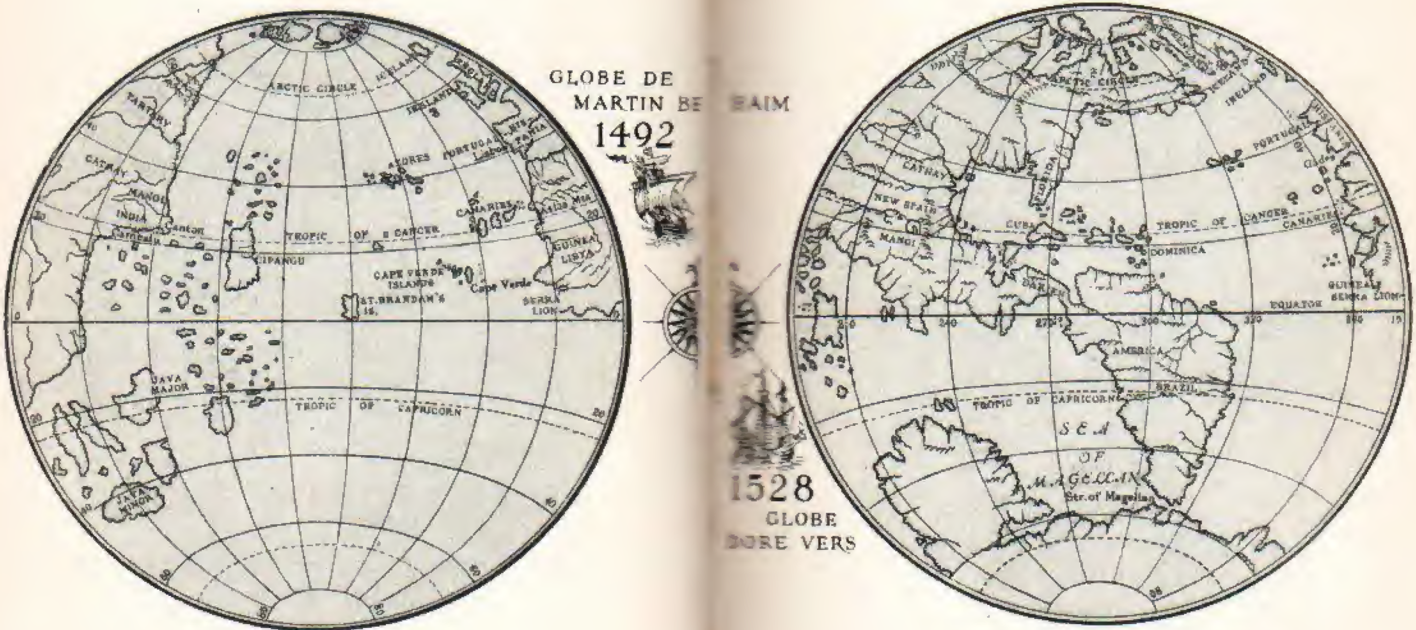
This circumstance has induced many to doubt of facts

AMERIGO VESPUCCI

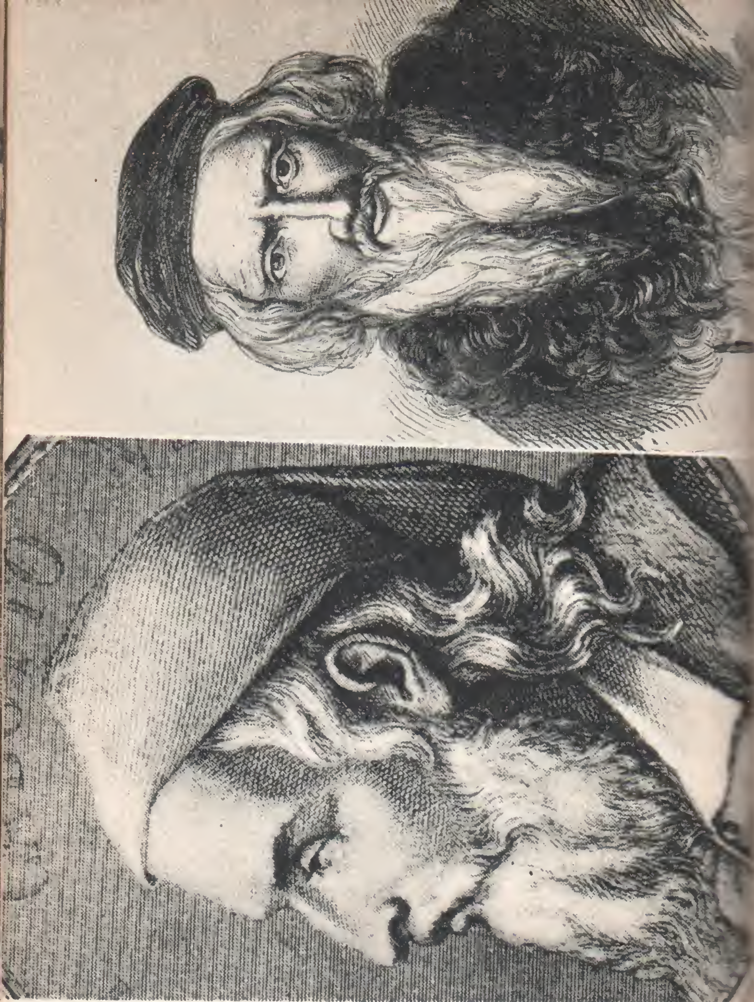
which have already been related. If, they contend, North America were really discovered and repeatedly visited by the Icelanders, how came a country so fertile in comparison with that island or with Greenland, or even Norway, to be so suddenly abandoned? This is certainly a difficulty, but a greater one in our opinion is involved in the rejection of all the evidence that has been adduced. The history is not founded upon one tradition or record, but upon many; and it is confirmed by a variety of collateral and incidental facts as well established as any of the contemporary relations upon which historical inquirers are accustomed to rely. For relations so numerous and so uniform, for circumstances so naturally and so graphically described, there must have been some foundation. Even fiction does not invent; it only exaggerates. There is nothing improbable in the alleged voyages. The Scandinavians were the best navigators in the world. From authentic and indubitable testimony, we know that their ships visited every sea, from the Mediterranean to the Baltic, from the extremity of the Finland Gulf to the entrance of Davis Strait.

Men thus familiar with distant seas must have made a greater progress in the science of navigation than we generally allow. The voyage from Reykjavik, in Iceland, to Cape Farewell, is not longer than that from the southwestern extremity of Greenland—once well colonized—to the eastern coast of Labrador.

But does the latter country itself exhibit in modern times any vestiges of a higher civilization than we should expect to find if no Europeans had ever visited it? The Jesuit missionaries say yes. They found the cross, a knowledge of the stars, a superior kind of worship, a more ingenious mind among the inhabitants of the coast which is thought to have been colonized from Green-



MAP OF THE WORLD IN THE DAY OF MAGELLAN



THE CABOTS, JOHN AND SEBASTIAN

land. They even assure us that many Norwegian words are to be found in the dialect of the people. The causes which led to the destruction of the settlement were probably similar to those which produced the same effect in Greenland.

The theory that the world is round dates at least from Pythagoras. It was Columbus alone that determined to prove the sphericity of the globe by actual travel: it was he that spent eighteen long years of travel from court to court, suggesting, imploring, bribing, threatening, wrangling, haggling, cajoling, till he secured his three ships. It was he that went forth to see what lay beyond the western horizon. He was he that held a mutinous, hysterical, superstitious crew under his will by threats, lies, prayers, and bribery. It was he that found land, and brought back natives, fruits, metals, maps, facts, allurements.

Columbus could not, of course, explore all he had discovered; but he was the forerunner of the swarm of explorations that became almost the chief industry of the time. It was paradoxical that he should have died in the belief that he had found India; but his mistake was soon discovered by the rest of mankind.

The personal character of Columbus has been a battleground. Men like Irving smoothed over his defects and enlarged upon the no-greater defects of men like Bobadilla; historians like Winsor dealt with his faults unsparingly. But it was the old truth that a man has "the defects of his qualities." If Columbus had been less mercenary he would not have haggled with the queen, or denied the seaman who first saw land his pension, or begun the slave trade as a means of wringing profit from the goldless islands; but neither would his dream of the wealth that would accrue from finding a water-

CORTEZ AND SMITH

way to India have upheld him in his long poverty and deferment. If he had been more rigidly honest and more merciful he would not have butchered the wretched natives and earned the bitter hatred of his subordinates and the suspicion of his superiors as he did; but neither would he have kept two log-books, one of them false, to deceive his crew as to the distance they had gone—he would have listened to their prayers, had pity on their anguish of terror, and turned back to Spain.

His vices were but the other side of the pendulum swing of the fierce, unending energy that made him the man he was and led him to the deed he did.

If mercy is shown to his faults, it should also be shown to the faults of his enemies and his well-meaning opponents. It must be remembered that Columbus promised Spain the vast trade of India and China—and gave Spain a savage wilderness of naked paupers living in jungles that absorbed vast sums of Spain's money and great numbers of Spain's sons. The disappointment was bitter, and as Columbus had made his appeal to Spanish cupidity, by Spanish cupidity he was judged. The adventurers returning in rags and sickness became beggars for the king's charity. When they saw the children of Columbus go about in splendor, they jeered at them as "the sons of the Admiral of Mosquitoland—that man who discovered the lands of deceit and regret—a region of graves and misery for the hidalgos of Spain."

To them Columbus was a failure as a discoverer. Even to us his failure as a governor was absolute and dire. He was the fanatic that does one great service to the world and with it outweighs a myriad of mistakes and crimes equally fanatic.

The discovery of what was supposed to be a western route to India, which was the first interpretation of the

DE SOTO AND THE MISSISSIPPI

successful voyage of Columbus, was hailed everywhere with the utmost enthusiasm. In the court of Henry VII in England, it was pronounced "a thing more divine than human." Says Washington Irving:

"Every member of civilized society rejoiced in the occurrence as one in which he was more or less interested. To some it opened a new and unbounded field of inquiry; to others an enterprise; and everyone awaited with intense eagerness the further development of this unknown world still screened with mystery.

"Notwithstanding this universal enthusiasm, however, no one was aware of the real importance of the discovery. No one had an idea that this was a totally distinct portion of the globe, separated by oceans from the ancient world. The opinion of Columbus was universally adopted, that Cuba was the end of the Asiatic continent, and that the adjacent island separated the Indian Seas."

Few of the early names in American history have failed to be the subject of critical dispute. None have been the victims of more bitter controversy than Vespucci, the Florentine, whose first name has been latinized and feminized into the title of the entire New World. There exists a letter credited to Vespucci which says: "We sailed from the port of Cadiz, May 10, 1497. After spending a few days at the Canaries, the four ships proceeded and arrived at the end of twenty-seven days upon a shore which we believed to be that of a continent."

If this letter is to be believed, Vespucci reached the continent a week or more before John Cabot, for whom June 24, 1497, is the earliest date claimed; and fourteen months before the date when Columbus sighted the mainland in August, 1498. Therefore there would be

VASCO DA GAMA

at least partial justice in giving the name America to the mainland. But this letter is in conflict with so much negative evidence that the 1497 voyage of Vespucci is not seriously accepted by the majority of historians, tho, of course, it cannot be entirely disproved to have happened in a crowded time when, as Columbus said, "the very tailors" wanted to be discoverers. The letter, however, was not written till 1504, if then, and it distinctly states that Vespucci went under royal commission. Of this there is absolutely no confirmation, which is suspicious; there is indeed some proof that he could not have been out of Spain in the period indicated.,

While Vespucci's voyage in 1497 is denied by almost all reputable historians with the exception of a few stalwart defenders like Varnhagen and John Fiske, there is little doubt that he made what he calls his "second" voyage, in 1499. Of this there is proof, for he is mentioned by Alonzo de Ojeda, who was with Columbus in 1492 and who in 1499 made an independent voyage with four ships by royal commission and reached the Orinoco.

In 1512 Columbus's son Diego, as heir to his father's rights, brought suit against the king of Spain for royalties from certain provinces. The king tried to prove that Columbus did not discover the provinces in question. Ojeda, called as a witness, mentioned his voyage in 1499 and stated that he took with him "Juan de la Cosa and Morigo Vespuche and other pilots." But he did not say that Vespucci had two years earlier discovered the mainland, tho he did admit that his own voyage in 1499 was made possible by a surreptitious use of the maps and journals made by Columbus in 1498. Nor did Vespucci's nephew, who was at the trial, advance any family claims for priority.

BALBOA AND PONCE DE LEON

The claim thus being further discredited, the question of Vespucci's intention to deceive is a new problem. The letters credited to him claim four voyages, two for the king of Spain, two for the king of Portugal. These letters appear as an appendix to the *Cosmographiæ Introductio* published in the small town of St. Dié in 1507. In the text the author says: "The fourth part of the world having been discovered by Americus, it may be called Amerige; i.e., Americus' land or America." He later reiterates the suggestion and explains the form America by saying that "both Europe and Asia have chosen their names from the feminine form."

The author of this book, Martin Waldseemüller, otherwise known as Hylacomylus, thus deliberately invented the word America in 1509. In 1522 it was placed on a map in an edition of Ptolemy's *Geographia*.

From that time its convenience and gracefulness have given it permanence. The problem of Vespucci's assistance in foisting his name on the New World is also in dispute. If he wrote the letters in which he claims to have made four voyages, of which the one he calls "the first" required seventeen months, while the one he calls "the second" was made in 1499, it seems hard to relieve him of a charge of intentional fraud. He deserves, however, the honor of planting the first colony of Europeans in South America, in 1503. In 1508 he was made pilot-major to King Ferdinand and he died February 22, 1512, apparently in high honor.

The contrast with Columbus is complete. Columbus spent years and years of land-travel and toil preparing the means to invade the unknown sea, found a world there, suffered — after a brief glory — ignominy, imprisonment, and neglect, and was buried with the chains he had worn.

CORTEZ

CHRISTIANIZING MEXICO

The year after his death, a suggestion was obscurely made that a certain minor navigator, Amerigo Vespucci, should be chosen as the sponsor for the New World. In proof of his right to the naming of a quarter of the globe, certain letters of his own were cited to the effect that he saw a coast which he thought to be a continent; this was five years after Columbus had made his first voyage. At best the letter utterly lacks substantiation, but evidence which would in a law court hardly establish a claim to an acre of ground has sufficed to fasten the name of a subordinate pilot upon a hemisphere.

The English explorers, John and Sebastian Cabot, have disputed with Vespucci, in the minds of historians, the honor of being first actually to visit the mainland of America. When reading the names of discoverers, it would seem as if all the world came soon after. But from amidst the multitude a few names stand out—De Soto, discoverer of the Mississippi; Balboa, who first viewed the Pacific Ocean from the American shore; Ponce de Leon, discoverer of Florida and famed for his quest of the fountain of eternal youth; Samuel de Champlain, "exploring with sword in one hand and crucifix in the other;" Sir Walter Raleigh, ill-fated colonizer; the Sieur de LaSalle, first navigator of the Mississippi; and John Smith of Pocahontas fame, or perennial notoriety.

The western route was barred to the Portuguese, but the eastern one remained open to them, and before the close of the 15th century Vasco da Gama had set out on the voyage that ultimately led him to India by way of the Cape (1497-1500 A.D.). Twenty years later another Portuguese navigator, Magellan by name, started on what must ever remain the most memorable of voyages, save only that of Columbus. Magellan rounded the

HUDSON IN TRIUMPH AND IN DESPAIR

southern point of South America and in 1521 reached the Philippines, where he died. His companions continued the voyage and accomplished ultimately the circumnavigation of the globe; and in so doing afforded the first unequivocal practical demonstration, of a character calculated to appeal to the generality of uncultured men of the time, that the world is actually round.

Two routes from Europe to the Indies had thus been established, but both of them were open to the objection that they necessitated long detours to the South. To the geographers of the time it seemed more than probable that a shorter route could be established by sailing northward and coasting along the shores either of Europe to the east or—what seemed more probable—of America to the west.

Toward the close of the sixteenth century the ships of the Dutch navigators had penetrated to Nova Zembla, and a few years later Henry Hudson visited Spitzbergen, thus inaugurating the long series of arctic expeditions. Then Hudson, still sailing under the Dutch flag, made heroic efforts to find the fabled northwest passage, only to meet his doom in the region of the bay that has since borne his name.

This was in the year 1610. For long generations thereafter successors of Hudson were to keep up the futile quest; and when finally it had been clearly established that no northwest passage to the Pacific could be made available, owing to the climate, the zest for arctic exploration did not abate, but its goal was changed from the hypothetical northwest passage to the geographical pole.

Henry Hudson had in his day established a Farthest North record of about the eighty-second parallel of latitude—leaving only about five hundred miles to be

THE POCAHONTAS EPISODE

DEATH OF LASALLE

MANHATTAN ISLAND AT A BARGAIN

THE FIRST THANKSGIVING

traversed. But three centuries were required in which to compass this relatively small gap. Expedition after expedition penetrated as far as human endurance under given conditions could carry it. Some of the explorers returned with vivid tales of the rigors of the arctic climate; others fell victims to conditions that they could not overcome. But the seventeenth, eighteenth, and nineteenth centuries passed and left the "Boreal Center" undiscovered.

Toward the close of the nineteenth century the efforts of the explorers seemed to be redoubled and one famous expedition after another established new records of "Farthest North." The names of Nansen, the Duke of the Abruzzi, and Peary, became familiar to a generation whose imagination seemed curiously in sympathy with that lure of the North which determined the life activities of so many would-be discoverers. So when in the early autumn of 1909 it was suddenly announced that two explorers in succession had at last, in the picturesque phrasing of one of them, "penetrated the Boreal Center and plucked the polar prize," the popular mind was stirred as it has seldom been by any other event not having either a directly personal or an international political significance.

The two men whose claims to have discovered the pole were thus announced in such spectacular fashion were Dr. Frederick A. Cook, of Brooklyn, and Lieutenant Commander Robert E. Peary, of the United States Navy. Dr. Cook claimed to have reached the pole, accompanied only by two Eskimo companions, on the twenty-first day of April, 1908. Commander Peary reported that he had reached the pole, accompanied by Mr. Matthew H. Henson and four Eskimos, on the seventh day of April, 1909.

ANNEXATION METHODS: PENN AND LaSALLE

The controversy that ensued regarding the authenticity of these alleged discoveries is not likely to be forgotten by any reader of our generation. Its merits and demerits have no particular concern for the purely scientific inquirer. At best, as Professor Pickering, of Harvard, is reported to have said, "the quest of the pole is a good sporting event," rather than an enterprise of great scientific significance. It suffices for our present purpose, therefore, to know that Dr. Cook's records, as adjudged by the tribunal of the University of Copenhagen, to which they were sent, were pronounced inadequate to demonstrate the validity of his claim; whereas Peary and Henson were adjudged by the American Geographical Society, after inspection of the records, to have accomplished what was claimed for them.

What has greater interest from the present standpoint is the question, which the controversy brought actively to the minds of the unscientific public, as to how tests are made which determine, in the mind of the explorer himself, the fact of his arrival at the pole.

The question has, indeed, been largely answered in our discussion of the sextant and the *Nautical Almanac;* for these constitute the essential equipment of the arctic explorer no less than of the navigators of the seas of more accessible latitudes. There is one important matter of detail, however, that remains to be noted. This relates to the manner of using the sextant. On the ocean, as we have seen, the navigator levels the instrument at the visible horizon; but it is obvious that on land or on the irregular ice-fields of the arctic seas no visible horizon can be depended upon as a basis for measuring the altitude of sun or stars. So an artificial horizon must be supplied.

The problem is solved by the use of a reflecting sur-

CHAMPLAIN AND HIS LAKE

face, which may consist of an ordinary mirror or a dish of mercury. The glass reflector must be adjusted in the horizontal plane with the aid of spirit levels; mercury on the other hand, being liquid, presents a horizontal surface under the action of gravitation. Unfortunately mercury freezes at about 39 degrees below zero; it is therefore often necessary for the arctic explorer to melt it with a spirit lamp before he can make use of it. These, however, are details aside from which the principles of use of glass and mercury horizon are identical. The method consists simply in viewing the reflected image of the celestial body—which in practise in the arctic regions is usually the sun—and so adjusting the sextant that the direct image coincides with the reflected one. The angle thus measured will represent twice the angular elevation of the body in question above the horizon—this being, as we have seen, the information which the user of the sextant desires.

Of course the explorer makes his "dash for the pole" in a season when the sun is perpetually above the horizon. As he approaches the pole the course of the sun becomes apparently more and more nearly circular, departing less and less from the same altitude. Hence it becomes increasingly difficult to determine by observation the exact time when the sun is at its highest point. But it becomes less and less important to do so as the actual proximity of the pole is approached; and as viewed from the pole itself the sun, circling a practically uniform course, varies its height in the course of twenty-four hours only by the trifling amount which represents its climb toward the summer solstice.

Such being the case, an altitude observation of the sun may be made by an observer at the pole at any hour of the day with equal facility, and it is only necessary for

PEARY

AMUNDSEN

IV—6

him to know from his chronometer the day of the month in order that he may determine from the *Nautical Almanac* whether the observation really places him at ninety degrees of latitude. Nor indeed is it necessary that he should know the exact day, provided he can make a series of observations at intervals of an hour or two. For if these successive observations reveal the sun at the same altitude, it requires no *Almanac* and absolutely no calculation of any kind to tell him that his location is that of the pole.

The observation might indeed be made with a fair degree of accuracy without the use of the sextant or of any astronomical equivalent more elaborate than, let us say, an ordinary lead pencil. It would only be necessary to push the point of the pencil into a level surface of ice or snow and leave it standing there in a vertical position. If, then, the shadow cast by the pencil were noted from time to time, it would be observed that its length is always the same; that, in other words, the end of the shadow as it moves slowly about with the sun describes a circle in the course of twenty-four hours. If the atmospheric conditions had remained uniform, so that there was no variation in the amount of refraction to which the sun's rays were subjected, the circle thus described would be almost perfect, and would in itself afford an indication that would appeal to the least scientific of observers. It should be observed, however, that the circle would not be quite perfect unless the observation was made on the day of the solstice; since at all other times the sun is either rising or falling.

But while rough approximations might thus readily be made, the attainment of absolute accuracy of observation would be quite another matter. The low elevation of the sun and the extreme cold would make accurate

instrumental observations difficult; and it is conceivable that the explorer who had the misfortune to encounter cloudy weather, and who therefore gained only a brief view of the sun, might be left in doubt as to whether he had really reached the goal of his ambition. Fortunately, however, the explorers who thus far claim to have reached the poles record uninterruptedly fair weather, enabling observations to be taken hour after hour.

Under these circumstances, there could be no possibility of mistake as to the general location, altho perhaps no observation, under the existing conditions, could make sure of locating the precise position of the pole within a few miles.

A curious anomaly incident to the unique geographical location of the North Pole is that to the observer stationed there all directions are directly south. Yet of course all directions are not one, and the query may arise as to how an explorer who has reached the pole may know in what direction to start on his return voyage. The answer is supplied by the compass, which—perforce pointing straight south—indicates the position of the magnetic pole and so makes clear in which direction lies the coast of Labrador.

Moreover, if the explorer is provided with reliable chronometers, which of course record the time at a given meridian—say that of Greenwich—these will enable him to determine by the simplest calculation what particular region lies directly beneath the sun at any given time. If, for example, his chronometer shows five o'clock Greenwich time, he knows that the sun's position, as observed at the moment, marks the meridian five hours (*i.e.*, 75° of longitude) west of Greenwich.

What has been said of observations made at the North Pole applies also (with obvious reversal) to observations

BYRD

made at the opposite axis of the earth. In everything else save in the matter of low temperature, however, conditions at these two extremes are utterly different. Sir Ernest Shackleton, approaching within one hundred and eleven miles of the South Pole in 1909, concluded that the high Antarctic Continent over which he had traveled must extend beyond his forbidden goal: that the South Pole was located on frozen land, not on a frozen ocean.

On December 14, 1911, Captain Roald Amundsen, of Norway, with four countrymen as companions, completed the task so nearly accomplished by Shackleton, by actually attaining the South Pole. He found this on a high plateau, some ten thousand feet above sea level, only to be reached after crossing mountain ranges, some of whose peaks are fifteen thousand feet high. So that, altho his journey was made on land instead of shifting ice, his task was quite as arduous as that of Peary and his companions. His own account of the crowning incident is dramatic in its simplicity.

"We had got our silk flag ready in the morning," he says. "We gathered round it now, each man taking hold, and together we planted it here—at the same time naming the plateau, on which the pole is situated, 'King Haakon the Seventh's Wilds.' We had reached the pole with three sledges and seventeen dogs"—five sturdy Vikings annexing a Continent.

It remained to explore the polar regions from the air—when the development of aircraft made this possible. The earlier attempts were made in balloons, but the results in several notable cases were tragic. The famous flight of Andrée occurred in 1897, but nothing was known as to details of the tragedy until 1930, when a party from a Norwegian sealer under Doctor Gunnar

THE ILL-FATED ANDRÉE EXPEDITION

NEGATIVES DEVELOPED THIRTY YEARS LATER

ESKIMOS

Horn went ashore on White Island and found the remains of a camp, with a canvas boat, and in the boat a book on the front page of which were the words: "The Sledge Journey, 1897."

Presently, with more tragic relics, a coat was found in a pocket of which was Andrée's diary. The remains of Andrée and his associate Fraenkel were found, but the actual cause of death can never be known. The entry of the last record bore the date of October 17, 1897.

The first successful flight over the pole was made by Commander (now Admiral) Richard Evelyn Byrd in an airplane piloted by Floyd Bennett, which reached the pole and circled about it on the 9th of May, 1926. Only four days later Amundsen, with the dirigible balloon *Norge*, sailed across the pole with sixteen men. Amundsen thus became the first explorer to visit both poles.

On November 28-29, 1929, Admiral Byrd, accompanied by Balchen and June as pilots and McKinley as camera operator, flew over the region of the South Pole.

They found it necessary to rise to an elevation of 12,000 feet above the great polar antarctic plateau. They circled over the region of the pole and returned to their base at Little America, in the Bay of Whales.

Admiral Byrd was thus the second man to visit both poles. He viewed them both from the air, whereas Amundsen, as we have seen, made his antarctic exploration by sledge.

The second expedition to reach the South Pole was that of Captain Scott, who gained the goal only to find there the evidences that the great Swedish explorer had preceded him. The tragic fate of Scott and his associates on the return trip may have been not altogether dissociated from the dispiriting experience of finding themselves forestalled in the great discovery.

There are still vast areas of both the arctic and antarctic regions that have not been seen by human eyes. But with the conquest of the poles, the age of major geographical discoveries may be said to have come to an end. Perhaps it should be added, however, that there are critics who are not quite convinced that any man has as yet set foot within a few hundred miles of the North Pole, notwithstanding the semi-official recognition of the extraordinary feat of Admiral Peary.

Polar expeditions will continue to be sent out, but it can hardly be said that the motive will be, in the old sense, the lure of the unknown. For no one questions that the floating ice sheet that covers the region of the North Pole has now been seen by many eyes. The antarctic exploration offers greater allurements, however, because the region there is continental, and its investigation may be expected to supply new evidence as to geological theory as well as other matters of scientific interest.

POTENTIAL PROGENY OF ONE BUTTERFLY

III

SURVIVAL OF THE FITTEST

MANY explorers, perhaps most explorers, have been lovers of nature. Their discoveries included observation of the animal life of the new regions they entered. To bring back strange creatures or their skins was an accepted part of the explorer's self-imposed task.

Even in our own generation there have been occasional discoveries of new types of animal life that have excited wide interest. Perhaps the most notable recent one was the discovery of the Okapi in Africa. It may well be doubted whether there remain any extraordinary forms of life that have not been seen and collected by man. Meantime there are hundreds of forms that are by way of disappearing, owing to man's influence. There are few more remarkable stories than that of the extermination of the passenger pigeon in America within the past half-century. The bison that once roamed the western plains by millions has now vanished, save for a few semi-domesticated herds. Some pessimists have gone so far as to predict that every form of larger animal, and a very large number of smaller ones, will disappear altogether from America within the coming half-century.

This is probably carrying cynicism too far. It is nevertheless true that efforts to conserve animal life have been undertaken none too soon in this country, and must be carried out very energetically if we are to save even the more significant forms of animal and bird life.

The simple truth is that man enters as a disturbing

factor—because of his unprecedented capacity to kill—even before the advance of civilization, with its necessary utilization of land for agricultural purposes, makes the terrain uninhabitable for many forms of wild life. On the other hand, by domesticating animals, man has preserved forms that might otherwise have disappeared. The domesticated animals, however, have in many cases departed so widely from their wild forebears as to be scarcely recognizable.

While our text will deal largely with the wild forms of life, and with the balance of nature more or less undisturbed by man, our pictures will tell the story of the modification of animals under domestication—in the service of man. Here, it will be seen, is a story of animal evolution under human guidance. If any one were to doubt that animal life in the past has developed from form to form, until the ultimate descendant is far removed from the original progenitor, such skepticism would vanish on observation of the unquestioned modifications that have been wrought by man himself in the development of many and varied races of domesticated animals.

Take the case of the dog, for example. It is highly probable that all dogs are descended from some one original wolf, or at most two or three species of wolves. In any event, all races of dogs are regarded as belonging to a single species, yet among familiar breeds there is diversity that would seem at a glance to establish a dozen, a score, or perhaps half a hundred species. Consider, as extreme examples, the St. Bernards, Mastiffs, and Great Danes on one hand and the numerous varieties of "toy dogs" on the other.

The races of horses, cattle, domestic fowls, and pigeons offer examples only a degree less striking. If sheep,

goats, and hogs are somewhat less diversified, it is because the human beings whom they serve have not found occasion to modify them by selective breeding except in certain predetermined directions—the sheep for fineness of wool, the hog for size, and the like. But no one doubts that selective breeding would avail to develop, in the course of generations, modified breeds of these and the other domesticated animals as widely variant as the observed races of dogs, cats, and domestic fowls.

Of course there is a time element involved. Doubtless the presumptive fact that the dog was the earliest animal domesticated offers a part explanation of the extraordinary diversity of modern breeds of that animal. On the other hand, there are instances, as in that of the Ancon ram, cited by Darwin, where a chance mutation has enabled breeders to modify a race of animals conspicuously in a single generation. In any event, the point under consideration is the ultimate modification, regardless of the time involved. And the thing chiefly to be noted is that the observed fact of the modification of animal forms under domestication offers a practical demonstration of the truth—no longer to be considered merely the theory—of animal evolution.

It is our present purpose to present certain aspects of the struggle under which wild life exists, and to point out, at least inferentially, the forces that operate, under natural conditions, to bring about on a large scale such modifications as man has wrought among the comparatively few species of animals that he has brought into subjection.

It will not be overlooked, on the other hand, that when natural conditions remain undisturbed, even for long periods, there is every reason to believe that the animal life remains correspondingly—at least relatively — un-

WOLF AND WOLF DERIVATIVE OF COMMON ANCESTRY

modified. This, however, is almost axiomatic. Let us turn to the illustrations of the thesis of survival of the fittest.

"Fittest for what?" That question quite obviously suggests itself in connection with the familiar phrase.

If we answer, properly enough, that fitness for the business of living is the thing in question, we only suggest a series of other questions: Living *when?* Living *where?* Living *how?* And by the time we have got the import of these questions, we are face to face with the entire problem of animal evolution. For the *When* involves the whole stretch of the scores of millions of years of the geological Era comprising the Ages of other Mammals and of Man. The *Where* compasses the zones from the equator almost to the poles. And the *How* implies habitats including all manner of conditions on the earth's surface; beneath the surface; in the treetops; in the waters of rivers, lakes, or oceans; and in the air.

It is clear that a creature fitted to live in, let us say, Greenland, when that land-mass was a part of the great Holarctic continent drifting up across the equator, would be eminently unfitted for life in the Greenland of today. The Alaska of today is the repository of bones of mammoths that once flourished there. The monster Columbian elephant that once was the "fittest" inhabitant of the region that is now the State of Indiana, was totally unfitted for life in the Ohio Valley when the climatic conditions were modernized. The mastodons that once dominated Manhattan Island are represented there today only by skeletons in the Museum of Natural History.

But while these colossal creatures, and sundry thousands of their fellows, vanished from the earth because they ceased to "fit" the changing environments, there were others of their contemporaries that are still in existence, some of them flourishing abundantly. For example,

musk-ox and walrus in Greenland; caribou and moose in Alaska; deer and fox and rabbit in the Ohio Valley; and rats, mice, bats and men on Manhattan Island. Clearly, the question of *How* an animal lives is highly important in determining its fitness for any given environment.

And back of the *How* is the *Why* of the behavior in question.

Why did the race that proved its fitness by dominating the world at one stage (a) attain fitness in the first place, and (b) lose its fitness in the second place?

Why have a thousand races perished for every one that remains?

Why? and Why? and Why? That is the ever-reiterated question that confronts us when we consider animal behavior of past or present.

We are told that the geological records show no fewer than sixteen distinct transformations of the mammalian populations of America. There is a certain historical interest in scanning the records of these populations—giant uintatheres, titanotheres, rhinoceroses, camels, mastodons, elephants, saber-tooth tigers, lions, and the multitudes of lesser contestants in the struggle for existence. But there is greater interest in asking *Why* the kaleidoscopic transformations took place.

It is that aspect of the matter that chiefly concerns us here. Certain facts of animal behavior must be presented, of course; but our main concern is not with the facts as such, but with their interpretation. Our interest lies in the *Whys* of the varied animal activities, rather than in the mere Hows. And what applies to habit or behavior applies also, as a matter of course, to the structural conditions that are correlative to the methods of living.

Let me illustrate my meaning with a single cogent

example. The case of the little kangaroo rat, a common resident of the Arizona deserts, will serve the purpose.

This little creature, famed for its jumping capacity, has a short neck, in which six of the seven bones are fused together, or consolidated ("ankylosed," in technical phraseology).

You can hardly be expected to become excited over that anatomical statement. Your interest may be only mildly stimulated when you learn that there is no other land animal in the world—of all the twenty-odd thousand species — that has neck-bones similarly fused together.

But when you are told that the peculiarity is shared by a group of *Whales*, the anomaly can hardly fail to arrest your attention. That only two groups of animals among the thousands should have solidified necks; and that one of these nonconformists should be a pigmy of the desert that never so much as tastes a drop of water (manufacturing its own blood out of dry vegetable matter), while the other is a giant that never leaves the ocean—this, surely, is a paradox to excite wonder.

Is there a normal ten-year-old boy or girl in the world who will not eagerly ask "*Why?*" when that paradox is brought to his or her attention? Why, in the name of wonder, should consolidated neck-bones be required to give "fitness" for living to a tiny desert rodent on one hand and a massive sea-dweller on the other—while no third tribe of vertebrate creatures requires such an equipment?

To attempt to answer such questions is an important part of the present interpretation of the philosophy of animal behavior.

In the light of paradox, the solidified neck-bones of the little kangaroo rat may become for the casual observer the most interesting feature of structure or habit of a creature whose peculiarities of form and manner of living have aroused general interest in naturalist and layman alike. But in the broadly philosophical view of animal economy the neck problem is only one of a long series of mysteries calling for explanation and interpretation. For instance:

Why has the kangaroo rat developed its hind legs disproportionately?

Why has it lengthened its tail till it equals the body length?

Why has its jacket become the color of sand?

Why does it live exclusively in the desert?

Why does it spend the day in a burrow underground, and venture forth only at night? Why? Why? Why? There is no limit to the question marks. You may put one after every statement of fact as to structure or habit of the little kangaroo rat.

And what is true of this little rodent is true, *mutatis mutandis*, of every other creature of the entire mammalian coterie. There is no structure, no habit, that does not call for interpretation. If we explain why the kangaroo rat has consolidated neck-bones and long hind legs and extended tail and fawn-colored coat and nocturnal habit, we must then explain why the little desert-dweller's cousin-german, the pocket gopher, has unconsolidated neck-bones, and small hind legs, and stubby tail and dirt-colored jacket, and the habit of working by day as well as by night.

And then we must ask why other relatives, like the familiar squirrel, have longer necks, and feet adapted for climbing instead of digging, and legs of symmetrical pattern, and bushy tails, and jackets of gray or tan, and the habit of working only by day.

WELL-DEFENDED PORCUPINE AND SKUNK

Or why yet another rodent relative, the porcupine, is as sluggish of habit as the others are active, and neither burrows nor climbs with facility, and wears a forest of spines on its back.

Or why the muskrat has taken to the water and developed webbed feet and a flat tail.

And so on and on throughout the list, not of rodents alone, but of the eaters of flesh, the wearers of hoofs and horns, and all the rest. For example:

Why did the saber-tooth tiger vanish?

Why did horse and camel and rhinoceros and elephant become extinct in America?

Why did porcupine and one opossum survive north of the Rio Grande?

Why does the skunk alone, of all our mammals, wear a strikingly conspicuous costume?

Why does the grain of the hair run toward the elbow on the forearms of sloths, monkeys, and men? Why? and Why? and Why?

The general answer to all the Whys, of course, is that Evolution has produced the endless modifications of structure and of habit in question in order to fit the members of the varied tribes for the business of living in varied environments, in diversified manners, under widely different conditions. Our business is to find the specific answer for each mystery. Back of every organism is a story of evolutionary development. This, indeed, is the story that we have to ferret out in our endeavor to explain the mysteries and paradoxes of animal structure and behavior.

In the course of that endeavor, we are led to observe that operation of Evolution is often very different from what it is commonly supposed to be. There are, in short, half a dozen paradoxes of the evolutionary process that

are brought repeatedly to our attention as we attempt to interpret the records of mammalian development.

This, obviously, is not the place to elaborate an aspect of the matter to which chapters of our text must be devoted. Yet it may not be amiss to cite a few of the paradoxes in question:

(1) Evolution is commonly supposed to imply progressive development. In reality, mammalian evolution has been largely a story of degeneration and loss of structures, rather than of any new creation. For example, fingers and toes and even legs may disappear, but no new member has ever been added.

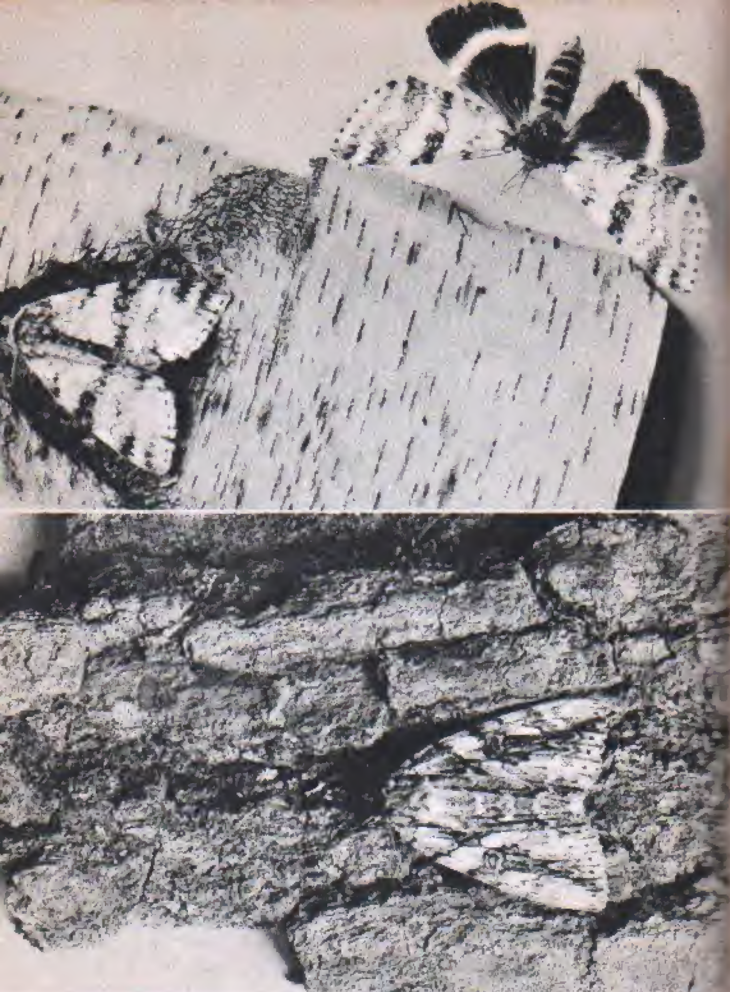
(2) Evolution is supposed to imply change. Yet the major part of the mammalian population, numerically considered, has altered very little for millions of years. If the animal populations could be retrospectively examined at intervals throughout the Age of Mammals, small creatures like mice and shrews and gophers and moles and squirrels would be found dominant at every stage. These, in general, have been the "fittest" to live and survive age after age. They persist, when specialized creatures perish. Their lack of specialization is their safeguard. They will probably still be "fit" and abundant after the human race has followed the dominant races of the past to oblivion.

(3) The basis of evolutionary descent is heredity; and the basic law of heredity is that every organism tends to transmit its own traits to its progeny. Yet the truth is that no creature is ever exactly duplicated in any offspring, and that Mendelian heredity explains how and why a child may be utterly unlike both its parents in some salient aspect—as when two jet-black guinea pigs give life to a pure white piglet that will breed true to whiteness.

(4) Evolution may be personified as the guiding mother whose watchful solicitude results in the developments that make the individual and the race "fittest" to survive. But the paleontological record shows that the net result of such ministrations is to develop specialized forms that are fitted to survive only while the environment remains unchanged. And since the environment is forever changing, it follows that Evolution, in the very act of making an organism "fit" to survive today, makes it unfit to survive tomorrow. In other words, Evolution acts as Nemesis, even while acting as benefactor.

(5) Evolution seems basically egoistic, since self-preservation appears to be "Nature's first law." "Fitness" implies competency to fulfil ruthlessly the ends of self-interest. Yet the altruistic spirit which is the highest endowment of the most advanced mammal is, of necessity, an evolutionary product.

(6) The moving force back of all evolutionary progress is the fact that every race of animals tends to increase at a geometrical ratio, and if unopposed would soon swamp the earth with its multitudes. Any considerable reduction in the fecundity of any race of animals that is merely holding its own in the "balance of nature" would presently result in the extinction of that race. Yet any race that was permitted to exercise its fecundity ("biotic potential") unrestricted would inevitably overstock the world and perish through famine. And the human race, having developed the power largely to control the "environmental resistance" that decimates the ranks of lower mammals, can avoid disaster only by the paradoxical procedure of lowering its biotic potential. In other words, the crowning paradox of human evolutionary development is that, for the highest mammal, birth control is the only alternative to race suicide.



CAMOUFLAGE

IV

CAMOUFLAGE AND "RECAPITULATION"

THE price of life with most small animals is invisibility. Even as the case stands, mice, shrews, rabbits, and the rest of the small-fry fraternity seem always on the brink of the grave. Statistically considered, their "expectancy" of life is hardly worth computing, the mortality rate in any year being, paradoxically, several hundred per cent of the total population existing at any one time. Only the enormous birth-rate keeps any of the smaller races in existence. If its members were suddenly to attain high visibility, nothing could save them from almost immedite annihilation. They would vanish almost automatically—at the behest of hawk and owl and snake, and of cat, dog, fox, skunk, and weasel.

The case of the larger herbivores, under natural conditions, is not greatly different. Even when mature animals have substituted speed in part for concealment, their young must remain unseen while the mother forages. The fawn that lies hidden in the bushes is given a spotted coat that mimics the mottled and sun-flecked background, and has inherited also the instinctive inclination to remain absolutely motionless when fox or wolf or bobcat passes near, and perhaps glares, unseeing, straight in its direction.

After the fawn is old enough to have acquired fleetness of foot, it may doff the spotted coat. But even then it will put on a garb of gray or tan that blends wonderfully with the woodland background. Many a hunter,

ANOTHER TYPE OF CAMOUFLAGE

quadruped or biped, passes a deer a few rods removed in fairly open woods, without seeing it.

It goes without saying that such matching of a mammal with its background is no accident. It is the work of Evolution. Indeed, it is among the most persistent and unending of all the jobs that Evolution is called on to perform. Animals are forever emigrating into new environments. Moreover, local environments are forever changing, as we shall have occasion to note more fully presently. In any case, no animal species finds itself long (in the geological sense) under precisely uniform conditions of environment; so there is perpetual need of adjustment to meet the new conditions.

How exigent this need has been at times in the past, is well illustrated by the case of the spotted fawn and its unspotted parents. Offhand, this discrepancy between parent and offspring seems altogether anomalous. Apparently like has not at all tended to produce like—but striking divergence instead. But the anomaly is readily explained, and an interesting aspect of the evolutionary story is revealed in the recital.

The gist of the matter is that the fawn does receive its spotted coat by direct inheritance, and that it *is* very like its direct ancestors. Only we must consider ancestors very remote. Time was when the founders of the deer clan wore spotted coats all their lives. They inhabited regions where the climate was more tropical than their present habitat, and the vivid sunlight dappled the woodlands with color and shadow most of the time—instead of only for a brief summer season, or by exception, as in our temperate zone. So it was expedient for the deer to wear spots permanently.

The same thing holds for many of the more distantly related members of the mammalian clan. The puma

LUNG FISH — PIPE FISH AND SEAHORSE

wears a coat of uniform tan, but puma kittens have spots and obscure stripings. The puma now lives in dull-lighted northern woods, or in mountainous country where rocks rather than foliage-shadows make the usual backgrounds. So its coat has been modified for the best camouflage effect under average conditions. But the spotted kittens tell that the remote forebears of the puma were permanently spotted. And so are his cousins, the jaguar and the ocelot, to this day—because they still inhabit densely wooded regions and never have wandered far from the tropic zone of blazing sunlight.

Another well-known animal of large size that has spotted or striped offspring, while itself wearing an unstriped coat in mature life, is the tapir. The five existing species of this family live in only two regions of the globe—and those regions almost precisely as far apart as it is possible to get on the same globe. Four of them inhabit a somewhat restricted area (varying for different species) between Brazil and Central America. The other lives in the Malayan Peninsula, at the southeast corner of Asia. There are few other cases of animal distribution more anomalous than that.

The anomaly is explained by the existence of fossils to show that the ancestral tapirs inhabited Europe and North America at a time when land animals could travel across the entire land surface of the northern hemisphere. The two groups of tapirs that remain are merely the remnant that escaped extinction when the climate became so inhospitable that creatures of their type could no longer survive in the northern continents.

But tho so widely separated, they have maintained their ancestral peculiarities in extraordinary measure—doubtless because the climatic conditions of the two new habitats are so essentially similar—and they have especial

interest for the evolutionist as exhibiting many characteristics of forms of life that were at one time dominant in America and Europe, but which mostly became extinct some scores of millions of years ago. For example, they all retain a fourth toe on the front foot—even if minimized and not greatly functioning—tho they belong unequivocally to the Order of odd-toed creatures.

From the present standpoint, the thing of particular interest about the tapirs is that all of them—the ones over in Malaysia and those in Central and South America—wear striped and spotted coats (white or fawn markings on a darker background) while very young, and put aside these coats for quite different garbs as they grow older.

And that is not quite the whole story. The four American species, when mature, are very similar in appearance to one another. All are of a nearly uniform dull, noncommittal color, calculated to make them inconspicuous along the river banks and mud-flats which they frequent. But the Malayan species has one of the oddest costumes in the animal world. Its head and shoulders are black, as are its rump and hind legs. But the central part of its body is pure white—as if a sheet were wound about it. To that extent the cousins have diverged during the millions of years since they had a common ancestor. It is only a surface change, affecting no essential feature of anatomy or function. Yet it constitutes, to visual observation, a very marked change indeed.

And now the point of the recital: If you were to secure half a dozen little tapirs of tender age, offspring of banded Malayan parents, and put them with half a dozen youngsters of American parentage, you would have a dozen cunning little creatures looking so much alike that you could scarcely distinguish between them—but looking not in the least like any of their parents. Yet in time they would grow up to represent five different species of tapirs. And in so doing they would in effect re-traverse the stages through which their respective parents passed in the long generations of their evolutionary development.

The striped youngsters are as much alike as members of one species, because they hark back to the same pair of ancestors that were members of one species. That pair of ancestors and their fellows were small, striped animals. And across the millions of intervening generations they are making their influence felt—proving that like *does* not only *tend* to produce like, but succeeds in actually producing it.

Such illustrations make it clear that Heredity is not necessarily defeated in the contest with Environment, even when seemingly defeated. The ancestral traits may be forced to yield precedence to newer adaptations, to meet conditions of changed environment, but the submerged traits are not necessarily eradicated. They may still find representative factors, or *genes*, in the germplasm of each individual of the race; and it may still be expedient to give tangible recognition to them for a season—as in case of the spotted fawn and puma cub and tapir youngsters—in the life-history of individuals to whom their permanent possession would be a handicap.

In a word, then, the mottled coats of the young animals are tangible illustrations of a basic evolutionary phenomenon that is extraordinary or quite-to-be-expected according to the way you look at it—the fact that each individual organism of any species whatsoever tends to reproduce in its individual development and

ARMORED BATFISH

growth an epitomized history of the past evolutionary history of its race. This so-called "recapitulation" begins with the ovum that is vitalized by the union of sperm cell and germ cell in the maternal body; it passes through the whole sequence of evolutionary development of the invertebrate and vertebrate scale, while the fetus is still *in utero*. And the later stages of mammalian evolution are epitomized in the successive changes from infancy through adolescence to maturity.

But there are not many phases of the whole amazing recapitulation that are at once so tangible to casual observation and so compellingly demonstrative as that presented by the mottled coats of the infant deer and tapir. The spotted fawn, securely hidden tho in plain sight there amidst the dappled sun-spots of the brier patch, epitomizes in its winsome person whole chapters of mammalian history. It symbolizes the very essence of Evolutionary philosophy.

DUCK-BILLED PLATYPUS

LIFE ZONES

V

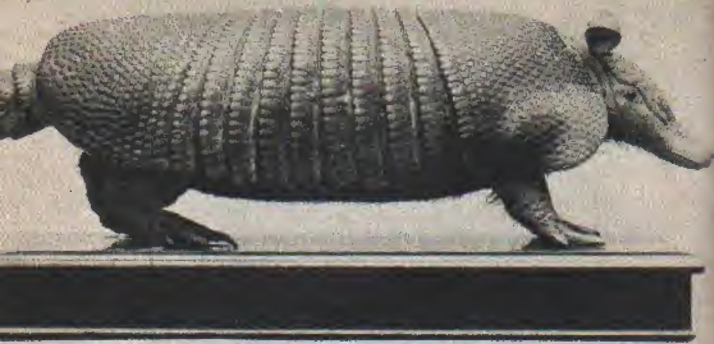
THE BALANCE OF NATURE

CIVILIZED man has well earned his reputation of the most wanton and ruthless of killers. Yet in general his destructive work has resulted in limiting the range of many large mammals, excluding them from parts of their former habitat, but not in total annihilation.

The extent to which animals have been locally extirpated may be illustrated by reviewing briefly the list of larger mammals that were former inhabitants of the region of New England where our wild-life sanctuary "Three Brooks" is located. The list is not very long, but striking. It includes the puma, the wildcat, the Canada porcupine, the otter, the beaver, and perhaps the wapiti deer and the moose. Doubtless the marten and the fisher may have been occasional visitants; also the wolverine and the badger.

These animals are either too large and conspicuous or too averse to the proximity of man to permit them to remain in a territory as fully settled as the New England of today. But all of them are still to be found in less settled regions of Canada or the western United States. All but the wapiti still exist in large numbers in widely spread areas of wilderness. We shall hear more of them in other connections.

Our concern of the moment, however, is with the creatures that are still to be found in settled regions, in more or less close contact with man. The question for



FORTIFIED: ARMADILLO AND HORSESHOE CRAB

answer is not why the vanished races have disappeared, but how the remaining races have been able to bid defiance to their human coinhabitants. For that is what they virtually have done. The chief bulk of the wild mammals that remain in settled regions are there in defiance of man. They have resisted his utmost efforts to exterminate them.

Take the woodchuck as a typical illustration. Every man's hand has been against him, here in New England, for upward of three hundred years. Yet if it were possible to make accurate comparison, more woodchucks could, I suppose, be counted in New England today than were here when the *Mayflower* landed. They are fair game for every boy who can muster a gun. They are trapped and shot, and caught by dogs, and poisoned in their burrows—and they outnumber the human population in the farm districts ten to one.

The explanation? Simply that the woodchuck has learned, through millions of generations of ancestral experience, how to take care of itself. Man's line of attack presents certain particularities—notably incident to the long range of firearms—that call for new lines of defense; but in general the same traits are requisite to escape death at man's hands that were needed for escape from the hosts of enemies that flourished before man's advent. Meantime, man's coming resulted in the banishment of some of the early enemies, and so helped balance the scale.

To make the matter clear, let us consider the project of making a living from the woodchuck's standpoint. At the outset, let us recall that there are two major problems confronting every wild creature—the problem of securing food and the problem of escaping from enemies that would destroy it. There is no wild creature

NEAR-FLIERS: FLYING SQUIRREL (YOUNG)
AND FLYING FISH

that does not have to work for a living—to work or starve. There is none that does not have enemies that would take its life, against which protective measures must be taken.

Unless we keep these two factors constantly in mind, we shall not understand the life-story of the woodchuck or any other animal. The whole story of animate nature must be a closed book to anyone who does not understand that life, for the animals of the wild, is a literal struggle for existence: a literal struggle to escape starvation on one hand and death by violence on the other. Whoever insists on seeing design in Nature must postulate a designing intelligence that reveled in carnage. The normal goal of every wild creature is death by violence or death by starvation. Rare indeed is the wild mammal that does not reach one goal or the other.

The woodchuck belongs to the moiety of the animal tribe born to serve as food for the predatory half of the clan. Its line of defense is primarily a capacity to vanish into the bowels of the earth when pursued. It cannot run speedily like a rabbit, nor scamper into trees like a squirrel; and it has no such weapons of defense as have been developed by porcupine or skunk. But it has learned how to dig a deep and widely branching burrow, with at least two openings for emergencies. And it has learned that it must never venture far from one of the doorways to its burrow without utmost caution of the order of "Stop; look; listen!" If you watch it from a distance, you will see that it never takes half a dozen steps, nor a dozen bites of grass, without pausing to raise its head, stand erect on its haunches, and look searchingly in all directions. Perpetual vigilance is its only passport to another hour of life.

Even at that the keen eyes may have failed to note

EAGLE AND CALIFORNIA CONDOR

the figure of a red fox, partly screened by yonder boulder, which stealthily approaches, moving only when the woodchuck's head is momentarily depressed in feeding, and drawing nearer and nearer—until it can make a dash which, if successful, will cut off the marmot's retreat, and write Finis to its career.

Such a dénouement as that is unusual, however, because the woodchuck has learned to retire to its burrow for the night just before dusk, a little earlier than the fox's time for foraging. By the same token, it escapes as a rule the attentions of the great horned owl, which only by exceptions starts hunting before sundown. For the rest, there is no regular daytime predator—with the possible exception of an extra-hungry red-tailed hawk—that would care to assault a full-grown woodchuck.

But of course it is only by rare exception that any woodchuck ever lives to become full-grown—or, for that matter, half-grown. If one woodchuck in ten that is born lived to attain maturity, there would be something like parity of numbers between woodchucks and blades of grass in every New England meadow.

Does that seem an extreme statement? It is, on the contrary, highly conservative. Let me support it by calling attention to the familiar but always amazing properties of what is termed a geometrical progression. The application will be obvious—and you will soon understand why the whole story of animal life and evolution is involved in the simple formulæ of the multiplication table.

You recall, of course, from your childhood days, the story of the guileless farmer who agreed to pay the blacksmith for shoeing his horse on the basis of one cent for the first nail driven; two cents for the second; four for the third; and so on doubling to the final nail of the

thirty-two. Perhaps you recall your own astonishment when the simple computation revealed that the single cent, doubled and redoubled thirty-two times, had grown to more than a million dollars. Even when you made the computation for yourself, and could not doubt its validity, it still seemed somehow unreal.

And so it is with a similar computation applied to the case of the woodchuck—or any other animal. Its implications seem too astounding to be believed. Yet they are inescapable. There in the meadow is a single pair of woodchucks today. But tomorrow there are four youngsters in the burrow. The population has not merely doubled, but tripled. Even if the infant mortality were fifty per cent, there would be two pairs of woodchucks in the meadow next spring. And if the same rate of increase and the same mortality continued, we have only to apply the horeshoe-nail computation to show that one pair of woodchucks of the year 1930 would be represented by offspring to the number of more than a hundred million pairs in 1962.

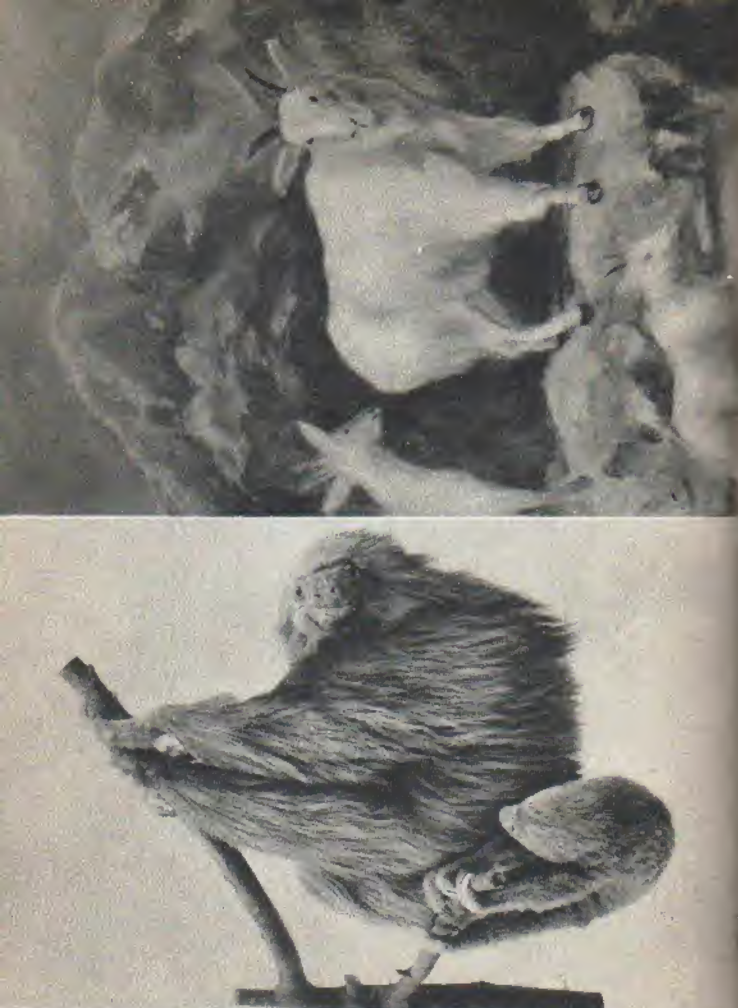
That is stating the matter in its simplest terms, and assuming that each pair of woodchucks breeds but once. In reality, of course, a normal pair would have several successive broods. The total population of the thirty-second year, all the direct descendants of the original pair, would number billions instead of mere millions. Wallace computed that even an animal having only a single offspring at a birth would have ten million descendants in forty years—if there were no premature mortality. And when you attempt to apply such a computation to an animal like the rat, for example, which may have four or five litters in a year, and which begins to breed at the age of six months—you simply run out of figures. It becomes obvious that a single pair could

bury the whole surface of the earth under their progeny within the compass of a single human generation.

A computation originally made by the workers of the Biological Survey as to potential development of English sparrows may be applied to the meadow mouse, which has four to eight young at birth, and may have several litters in a year. The computation shows the potential population that might be the direct descendants of one pair of mice in ten years to number 275,716,983,698 individuals.

Taking the land surface of the globe as 54,487,300 square miles, this would give more than 5,000 meadow mice to every square mile of surface, across the length and breadth of every continent and island. Or, to bring home the illustration still closer, three meadow mice to every square yard of surface—not merely in our meadow, but in every other square yard of land surface of the globe.

Allow a second period of ten years, and of course each pair would duplicate the record of the original ancestral pair. We should then have more than four hundred billion meadow mice to every square yard of surface. And this would give a bulk of mice, by conservative calculation, to pack space, like sardines in a box, to the depth of more than a million miles, round the entire globe, land surface and water surface alike. And it requires only pencil and paper and the multiplication table to prove that not so very many more years would be needed to extend the solid mouse population to the limits of the solar system—and on to the bounds of the visible universe, if your paper holds out. You may presently have the mice catching up with Dr. Hubble's flying nebulæ, a hundred million light-years distant, and receding at the rate of 12,000 miles per second.



SURE-FOOTED: SLOTH AND MOUNTAIN GOAT

Do you see the import of such a computation? It is absolutely basic. The oft-cited "balance of nature" hinges on it. The whole scheme of evolution depends on it. Obviously, premature death for the major part of the animal population is the price of racial preservation. If there were no check on the "normal" increase of woodchucks, for example, our meadows would be devastated, and the entire woodchuck population would die of starvation.

So it appears, paradoxically, that foxes and owls and hawks—along with snakes and weasels and other predators that feast on young woodchucks—are essential to the perpetuation of the race of woodchucks. Sweet are the uses of adversity.

PRO-ECHIDNA

KILLERS: ARCTIC BEAR AND AFRICAN LION

VI

THE PROFESSIONAL KILLERS

IN human warfare there is perpetual rivalry between projectile and armor. The invention of a stronger bow calls for a thicker coat of mail. Bigger cannon necessitate heavier armor-plate. The bomb-dropping airplane calls for new types of upward-pointing field guns. And in all this history is merely repeating itself—at an interval of billions of years. For just such a struggle between offensive and defensive mechanisms, without reaching final issue, has been going on in the world since animate creatures were first evolved.

Our present concern, naturally, is only with more recent aspects of the struggle, as represented by mammalian contenders. We have to note a few specific instances of the way in which animals that must secure meat for their dinners have been provided with equipment more or less adequate for the task. We must not forget that Evolution seems to look quite impartially on the opposing hosts — showing no preference for vegetarians, for example, as against flesh-eaters, but equally ready to help one or the other, as occasion offers.

And so we find (to cite a few near-to-hand examples) that the squirrel, climbing to hoped-for safety in the treetop, and thereby escaping fox and skunk, may find itself pursued to the farthest branches by a slim-built quadruped scarcely larger than itself, but of an aspect that suggests sinister things; a brown-furred creature with far-reaching neck and wicked eyes, and with carnassial

RELATIVES: BLACK FOX AND SPOTTED HYENA

teeth to match; a creature that is even more quick and agile than the squirrel itself—and showing in its every move that it has a will-to-capture that at least matches the squirrel's frantic will-to-escape.

This ruthless pursuer is called a marten. It is a larger cousin of the weasel, which has learned to climb (through long generations of evolutionary training), not to seek an avenue of escape, but as an additional aid to making a living. And it is clear that the marten must have learned to climb rather better than the average squirrel in order that his skill shall prove remunerative. If you watch for the sequel, you will probably be distressed to observe that the killer's professional training has not been in vain.

But the episode may not end with the capture of the squirrel. It is quite within the possibilities that before the marten can reap the reward of his victory, another climber may suddenly appear on the scene—perhaps racing with mighty leaps from bough to bough from a point of observation in a neighboring tree. This is a much larger animal, dark in color, but in form like the marten, and in manner even more vitriolic.

You know this intruder as a fisher. He has not come to the rescue of the squirrel, as perhaps you had hoped. He intends to secure a dinner for himself—and the marten will be lucky if his own flesh does not lend variety to the banquet. The flesh of a carnivore is doubtless not so palatable as that of a vegetarian like the squirrel. But the fisher may be hungry enough not to be overparticular. At any rate, you may be sure that no cousinly scruple will keep him from killing the marten if he overtakes him—and the fisher is credited with being the swiftest and skilfulest climber of them all.

Incidentally, the fisher is as courageous and as crafty

as he is active and swift of movement. Well as he climbs, he is quite as much at home on the ground, and on occasion may even take to the water. He could kill fox or raccoon in a fair fight, tho he is not so large as either. From wolf or puma he can escape by climbing. A lynx could not follow him to the higher branches—even if it dared attack him at all. Snow and cold have no terrors for him, his furry jacket being impregnable (I need not remind you that it has received the cachet of enthusiastic human approval). Almost his only danger is that his activity of today may so deplenish the supply of squirrels, rabbits, and allied food-products that there will be none available for tomorrow.

That is to say, this *was* his only danger until there came an enemy even better equipped for killing than himself—a killer who does not need to climb to reach the treetops; nor to run in order to overtake the fleetest set of legs; nor to fight in order to vanquish the most efficient fighter. Now that this greatest killer of all has come, the fisher and others of his ilk must retire to the farthest wilderness, and presently vanish altogether—as one coterie after another of killers has vanished in the past. Evolution has done much for him and his furry confreres—but *more* for the new generation of killers that is by way of superseding him.

And here, again, history but repeats an old, old story. That aspect of the matter, however, does not at the moment concern us. Let us seek another illustration of the impartiality of Evolution, as between defense mechanisms and the counter-mechanisms of destruction.

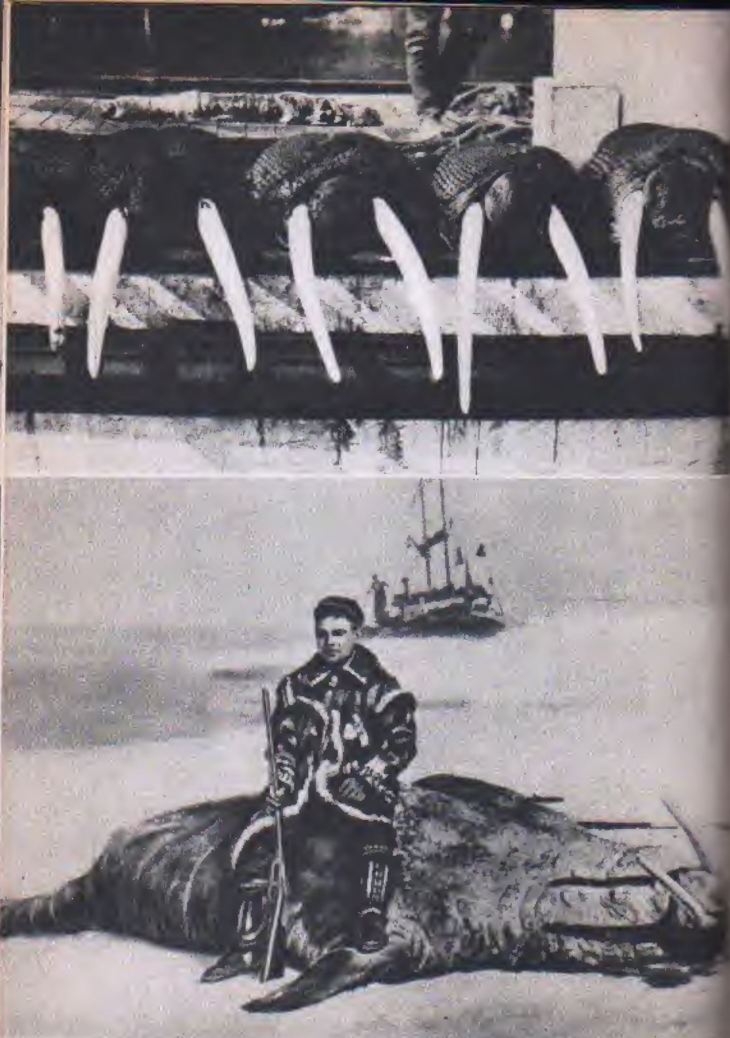
Consider, for example, the case of the famous diggers. It does not greatly matter which one is selected—woodchuck or mole or pocket gopher or prairie dog. All are for the most part vegetarians, and therefore probably

of toothsome flesh. About the only choice comes from difference in size. Here the woodchuck has first claim. But, on the other hand, the prairie dog does not in general burrow quite so deeply, and besides, lives in colonies, so that there is an unending series of their food reservoirs available without seeking. So let the choice be there.

The breadwinner who reasons thus is, of course, a badger—a low-hung, broad-gage animate craft, suggesting a turtle with hair-thatched shell, a masked face, and feet with extra-long and strong claws. A mechanism built for digging, as you discover at a glance. For defensive digging, too, on occasion—for the digging of a burrow into which he can retire should a wolf chance to come by and look on him with covetous eyes. But for the moment the badger is not thinking of defense. He is seeking his dinner. And he knows where to find it. Watch him now as he dives his nose into the opening of one of the prairie-dog dwellings and begins to make the dirt fly with those great talons. Evidently Evolution has prepared him with an equipment precisely adapted to this need. Almost in a jiffy he disappears, and you know that his dinner is to be not long deferred. Hardly work enough to get up a good appetite, one would judge—but not on evidence furnished by the badger.

Decidedly an easy way of making a living, in summertime. And the winter offers no problem at all. For then the badger curls up in the bottom of a burrow, and goes to sleep, and forgets even about eating — until spring comes, and the frost leaves the ground and again there is good digging.

You could hardly ask a prettier example of evolutionary adaptation than that. But think of the millions of generations required to develop so perfect a mechan-



CLAM-DIGGING TUSKS OF THE WALRUS

ism. And at that the badger is commonly regarded as a rather inferior example of Nature's handicraft, when the great coterie of efficient killers is under consideration. And, indeed, it must be admitted that he is decidedly "unspecialized" in comparison with some of his cousins. There is no other member of his immediate family (mustelidæ), from the tiny weasel to the giant of the clan, the wolverine, that is so sluggish-minded as to give up working (and, virtually, living) in the winter; or so sluggish-bodied as hardly to be able to do more than waddle. Yet, on the other hand, what one of them can beat him at digging? Every man for his job.

And, after all, Badger's job is a useful one, even if plebeian. Must not ground squirrels and mice and prairie dogs be kept in check? We shall hear of 400,000,000 prairie dogs in a single "village." Against such prolificness, many hands must join. And ground squirrels are an even greater pest, because more widespread. Even man finds it difficult to compete with them. In California the State pays thousands of dollars annually in bounties for scalps of the ground squirrel—having first killed off the badgers and paid bounties for the scalps of coyotes, in order to give the smaller pests a chance to proliferate. Ground squirrels could never thrive like that if there were not a shortage of badgers and coyotes.

But, as always, the story has another side. Badgers in the pursuit of their regular vocation make big holes. And they do not bother to fill them up again. Holes like that are a menace to the legs of horses and cattle. So the badger cannot be tolerated. And as to the coyote, his reputation is too well known to need airing. He is a chicken thief and a sheep thief. He does not scruple to kill a calf or a colt. If hungry enough, with a band of his fellows, he might even pull down a crippled steer.

The killer of killers cannot be expected to tolerate such a competitor. So of course the coyote must go. His larger confrere, the timber wolf, has already been banished from every civilized community.

When such larger animals as these are in question, then, we must think largely of the recent past, rather than of the immediate present. It is the "balance of Nature," without taking civilized man into account, that we have to consider in asking how animals live, and why they came to be what they are. And at every stage of that inquiry we are given new examples of the salient principle that the business of life for animals in general is—how to *secure* food without *becoming* food. It is the "balance" between eaters of vegetable food and the eaters of the vegetarians themselves that is in question.

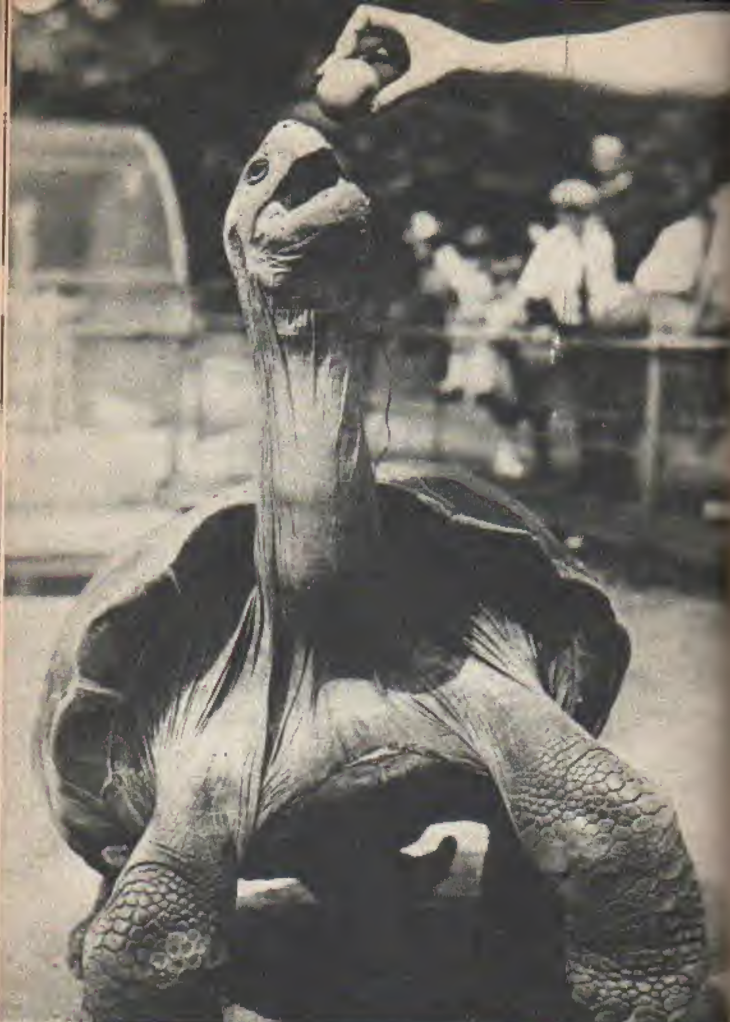
In the contemporary world we find the various coteries of killers specialized, as a matter of course, to prepare them to overcome one or another similarly specialized type of defense mechanism. We have just noted examples—the climbing marten and fisher, the burrowing badger, the cursorial wolf. Other even more familiar examples are the cats of various species, from lynx and bobcat to puma and jaguar; the bears, black, grizzly, brown, and polar; the foxes, gray, red, blue, and Arctic; the water-loving mink and river otters and sea otter; the fierce weasel and glutton and the less aggressive skunk and raccoon; the numerous true seals and their allies the sea-lions and walrus; and the great company of master-mariners ranging from porpoises to killer whales and cachelots (sperm whales).

Amazing diversity of form and habit. If we add to the list the little shrew, we have named among the predators the smallest mammal that is known to exist, and the largest vertebrate, it is believed, that ever existed.

Yet all these diversified creatures hark back to a common ancestor—if you go far enough. Moreover, you do not need to go, in a geological sense, so very far. Not more than a third of the way back to the time of beginnings of mammalian life, in all probability. In chronological terms, perhaps not more than three hundred million years—with leeway of a few score millions. The record, to be sure, is far from complete. Indeed, the earliest, and therefore the most interesting, part of the record is non-existent—or at least quite undiscovered. Yet enough is revealed in the record in the rocks, coupled with what the existing organisms themselves tell as to their ancestral affinities, to justify—indeed, to make imperative—the verdict of common ancestry for all the true killers (Carnivora) at a period not more distant than the Middle Eocene; possibly even in the still more recent Oligocene. In other words, well within the farther limits of the Tertiary, or so-called Age of Mammals; and at a time when mammalian history as a whole was far past its mid-period.

To be specific, it is believed that all existing branches of the professional killers called Carnivora (and many extinct races of intermediate or collateral stock) are descended from a somewhat primitive Order of killers called Creodonts. It is almost equally certain that the seal group had the same origin; and the inclusion of all the Cetaceans (whales) in the same category is only a shade more problematical. The shrews are of a yet more primitive stock. But if we were to go back a little farther we should find their ancestral lines converging toward the Creodont forebears.

In the *final* analysis, of course, both these and all other mammalian stocks would trace back, converging, to common ancestry.



PORTABLE FORTRESS FROM GALAPAGOS

VII

MECHANISMS OF DEFENSE

WHEN mechanisms of defense are in question, one naturally first thinks of the equipment of the skunk. It is indeed a strange mechanism—that pair of fire-extinguisher glands which can eject with deadly precision a stream of fluid with the biting quality of mustard gas and an odor unbelievably penetrating and persistent, which no language can describe, but which has made the word "mephitic"—derived from the skunk's generic name, *Mephitis*—a type-word for intolerable smells.

We need not wonder that the possessor of such a weapon can flaunt his spectacular black and white costume in the face of enemies thrice his size, and thrive and prosper throughout the length and breadth of the continent. Lacking that almost impregnable defense, no creature of its size could ramble in the open, and advertise its presence with such a costume, and live to tell the tale.

No other creature even makes the attempt. Every other small animal in the world (with the possible exception of the porcupine) has developed a costume that has at least a fair degree of camouflage value. The skunks alone are dressed for conspicuous display—for contrast with their background, rather than harmony with it.

There are almost no small black animals in the wild state, because dead black backgrounds are almost unknown, even at night, in Nature. The landscape painter

has no need of black pigments. If he carries his purple close to blackness on occasion, it is for contrast to make up for the relative dulness of his attainable highlights. A black animal in a painting disturbs all the values. I know a painter who regards a Holstein cow on a hillside pasture as the type of inartistic monstrosities. Needless to say, there is no wild ungulate that wears any such eye-compelling costume. The zebra's striped jacket is by no means an exception; for it is the uniform testimony of African hunters that the bizarre stripes have high camouflage value amidst tall grass under the tropical sun, and against the typical landscapes of the zebra's habitat by moonlight.

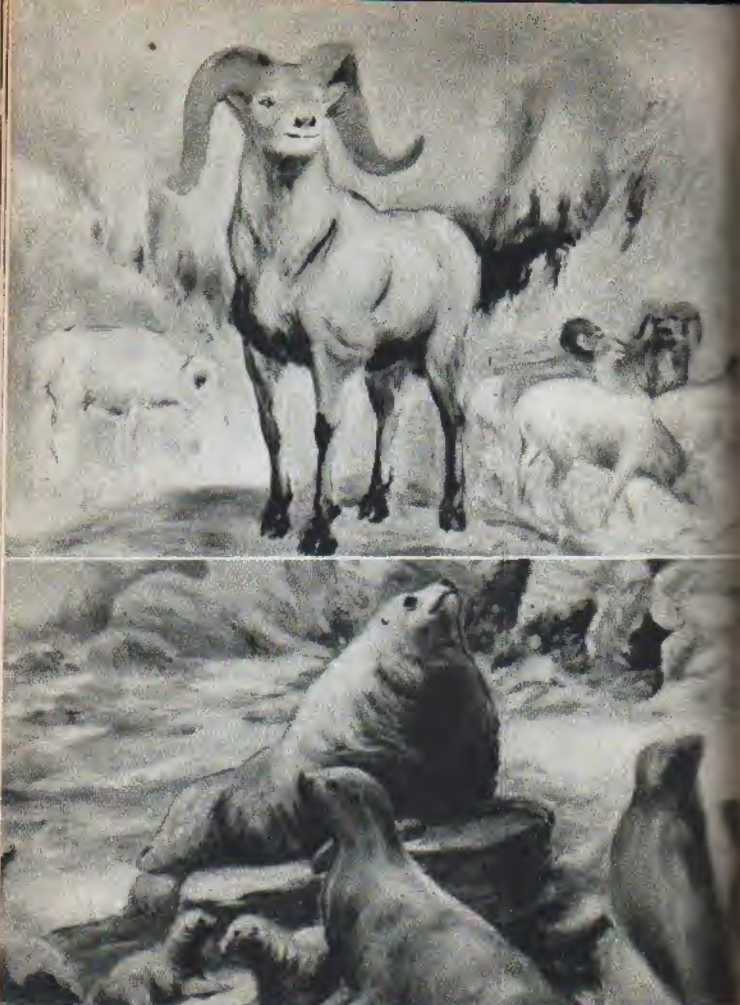
But no such thing can be said of the equally bizarre jacket of the skunk—a costume doubly anomalous because of the distribution of the colors. As if it were not enough to defy precedent by choosing black and white, the latter is displayed on the animal's back—either as a solid mass or in stripes or patches—whereas with rare exceptions animals wear dark-toned pelage above and lighter below, if they affect any difference of tone at all. The reason for this is plain enough—tho few if any naturalists fully appreciated it till the artist, Abbott Thayer, demonstrated that such disposal has camouflage value, because light comes from above and puts the lower part of the animal's body in shadow that equalizes the tone as interpreted by the eyes, and thus makes for invisibility. To reverse the distribution obviously accentuates the contrast. And when the tones are originally at the extremes of the scale—black and white—the result of putting the white above is to carry contrast to its upper limit, and insure the highest attainable degree of visibility.

After saying this, it may seem paradoxical to add

that the skunk's costume has been developed to meet the need of protective coloration. "Protective coloration!" you exclaim. "*Protective?*" Yes, I mean just that. The bizarre coat of *Mephitis* has been evolved, like the coat of every other mammal, to protect its wearer. It has been made conspicuous, because safety for this particular animal lies in being seen. Of the skunk, as of almost no other beast, is it true that it pays to advertise—and to advertise in the most demonstrative and unequivocal terms. "I am the fellow that carries the weapon no one cares to face," is the message he must convey instantly to every great horned owl that chances to fly overhead and to every fox that wanders within eye-shot.

If by any chance the message should fail to be correctly interpreted—if an obscurely seen form should be mistaken for that of a rabbit or a young raccoon, for example—the predator would strike with lightning-like rapidity and momentary success, even tho it found itself an instant later madly retreating, half suffocated, and bitterly regretting its Pyrrhic victory. Now and again such a mistake is actually made.

More rarely it happens that an owl or a fox, on the verge of starvation, dares to make the attack knowingly. In such a case, the issue is certain. Any full-grown great horned owl or red fox can kill a skunk at a stroke—if it dares to make the attempt. It may even happen that the fox breaks the spine of its intended victim so suddenly that the dreaded gas-engine is put out of commission unused. I once had proof of this in finding remnants of a skunk's pelt at the doorway of a vixen's burrow, when there was no effluvium in the air to suggest that the famous defensive weapon had been brought into action. Presumably the fox, emboldened by the imperative need to supply food for her offspring, had



PROTECTIVE ENVIRONMENTS: BIGHORN AND SEA LION

managed to dart forward and administer the coup before the victim realized its danger.

But such episodes are rare. Under ordinary conditions, owl and fox may be counted on to give the skunk a wide berth. Their keen eyes will not often mistake that white-backed prowler for any less vulnerable creature; and seldom will they muster courage to match their prowess against the most effective defense that Evolution has provided for any mammal.

The *most* effective defense? Superlatives are proverbially dangerous. Are we quite sure that the superlative is justified, even in speaking of the skunk's almost fabulous equipment? Have we not just admitted that *Mephitis* is on occasion found vulnerable; and that it *might* be killed any time by certain predators that need only screw up their courage to attack it? Let us not forget, then, before handing over the blue ribbon for defense mechanisms, that there is one other mammal abroad in the woods—a mammal not so very much larger than the skunk—which no owl or fox or wolf or even puma would ever dream of attacking, even with starvation as the alternative; and over which no one of these predators is likely to score a victory if by the inadvertence of mistaken identity an attack were made.

The mammal in question is, of course, the Canada porcupine. His defense mechanism has no such offensiveness as that of the skunk. It is purely a defense mechanism, with no quality of the offensive, except at very close quarters. But it is a defense so impregnable that no predator but one of the entire company of Carnivores is credited with ever being able to penetrate it. The owl or eagle or fox or puma that strikes at a porcupine will not merely suffer discomfiture, but will be lucky to escape with its life. For the quills that bristle at every

angle from the curled-up, almost globular, body—the animated pin cushion, with barbed spear-points instead of pin-heads projecting—which the porcupine becomes when assailed, have power not merely to stick in the face and lips and tongue of the predator, but to work their way deeper and deeper, until they penetrate to any depth. There is small chance that any creature without hands can pull them out, and their presence may prove utterly incapacitating, even should they fail to reach a vital organ.

The porcupine has no power to "throw" his quills. He does not spring forward to implant them. But he sometimes backs toward an enemy, and he can swing his tail sidewise with a devastating swish, implanting a miniature forest of quills in any object it reaches. Experienced campers in a woodland region of the porcupine's habitat are always on guard if they chance to be moving about at night, against stumbling on a quill-bearer that may have come to camp in quest of food or of any trace of salt that may be accessible.

It appears that salt has a strange fascination for the porcupine. Seemingly the sodium content of its normal dietary must be deficient, for the creature will go to any lengths to secure even the smallest quantity of this element. It will gnaw at and practically consume a board on which a salt solution has been spilled. It has been known even to gnaw deep into the handle of a spade or ax that bore some trace of salt from human perspiration.

Its fearlessness of man is part of the porcupine's general philosophy of life—the outgrowth, of course, of well-justified confidence in its impregnable habiliments. It is well aware that no animal dare attack it, and so there has been no need to develop *fear* as a prominent

attribute of its mentality. Most other animals must be perpetually on the alert, and ready to take alarm at the shudder of a leaf or the snap of a twig. Note how a horse, after centuries of safety from attack, still cannot help shying at an unexpected sound or the sudden advent of a wind-borne scrap of paper. The instinct to seek safety through sudden movement lies deep, and had far-off origins in ancestral germ-plasm. If the porcupine has lost that instinct, it is because the unique quill-defense it bears has been the endowment of its race for millions of generations.

That such is indeed the case is witnessed by the far-flung habitat and wide diversity of present forms of the creatures that have a similar endowment. It will be recalled that the echidna, the primitive monotreme egg-layer of Australia, is a quill-bearer. The capacity to develop spines was therefore, we may assume, developed at a very early stage of mammalian history. This is verified by the discovery of fossils generically identical with the modern hedgehogs in early Miocene strata. The hedgehogs—famed for their porcupine-like quill equipment—are widely distributed over the three continents of the Old World, and diversified into a score of species.

The "true" porcupines, or ground porcupines, are rodents, of equally wide distribution from the East Indies to Africa, including parts of Europe. They are so widely divergent as to rank as of different Family from the tree porcupines of the western hemisphere, of which the Canadian species is the only North American representative, but which has many species in the southern continent and in Central America. These southern representatives of the family have long prehensile tails, like those of the opossums.

If we add that there are even species of mouse-like or

shrew-like Insectivores in Madagascar that have coats of spine-like hairs, making them look like little hedgehogs, it will be evident that the device of arming small and otherwise helpless animals with quills for defense is an expedient to which Evolution has resorted on a most comprehensive scale. There are obvious reasons why such an armament would not be practicable for very active climbers or runners or for burrowers or predacious creatures that must move swiftly. But for animals that can secure food while still moving sluggishly, such a defense mechanism as that of the porcupine is almost ideal. It is said that the big arboreal weasel called fisher is able to overturn the porcupine, and kill it by striking at its quill-less abdomen. But I venture to doubt whether even the redoubtable fisher finds this always a safe experiment; and there is no other predator that is credited with even trying to match its prowess against this appallingly dangerous armament.

There is only one other type of direct defense mechanism, in the whole range of mammalian development, that could be named as comparable in value to the respective equipments of skunk and porcupine. This is the bony carapace of the armadillo and its allies. This covering suggests the shell of a turtle, except that it is variously jointed. The most northerly species, which extends its range into Texas, is known as the nine-banded armadillo, because the center of its body (above) is circled by nine bony bands, while the shoulders bear one immovable shield and the hips another—the whole constituting, as viewed casually, a single coat of mail, which extends also to the top of the head, even to the nose-tip. The tail is also plate-armored.

The lower part of the body is hair-covered and vulnerable, tho the surface exposed is minimized when the

animals coil up defensively. One small species of armadillo is said to be able to coil into a complete ball, and actually to escape its enemies by rolling along the ground. I am not aware that photographic confirmation of this habit is available. But we are assured on good authority that the European hedgehog and the unique scale-covered pangolin of Africa and the Orient sometimes adopt the same subterfuge.

The armadillos belong to the primitive Order of Edentates, or "toothless" animals—a curious misnomer as applied to this group, since some members have upward of forty teeth in each jaw (95 all told in one recorded instance), which is double the "normal" mammalian equipment, and more by far than any other mammal can boast, except possibly some of the porpoises.

There are other members of the Order, however, notably the anteaters, that are really toothless, and no member of the group has a really normal dental equipment, according to the standards of more advanced representatives of the mammalian clan. The armadillos, if not actually toothless, often lack entire groups of teeth. Our own armadillo, for example, has neither incisors nor canines. Its premolars and molars make amends, however, and total either 28 or 32—the latter number being, it will be recalled, the human complement, tho quite differently distributed.

The indeterminate tooth-equipment of the armadillos, and various other anatomical features, mark these animals as of a very primitive type indeed. Few other groups of mammals have been modified less by Evolution since the time of origins than the Edentates. Some of them, to be sure, have been greatly enlarged in size (especially some extinct forms, like the Glyptodonts), but there are others that still retain something like the

dimensions of their primordial ancestors. One of these, the little pichichago (*chlamydophorus*), is only about five inches in length, and has the armature in part reduced to horny plates, lacking the underlying dermal bony development of larger members of the fraternity. The plates, moreover, are not discontinuous at the neck, and they are not arranged in movable rings.

It seems likely that this is the more primitive type of armoring, and we cannot doubt that it dates back to a very early period. There was probably a time when a large percentage of the mammalian population (in the midst of a world of predatory Saurian giants) were creatures not so very different from the little pichichago (or pichy-ciego). One of the very first things that Evolution had to do, if the new race of mammals was to be preserved, was to develop mechanisms of defense that would serve a relatively sluggish little beast living on the ground. And the modification of hair into horny scales, and of skin into bony plates was an expedient that appears to have been early adopted, and to have served its purpose well.

The horny and bony coverings of the little creatures cannot have been adequate protection, of course, against being snapped up in the mouths of large reptilian predators. But they may have sufficed to make the tiny mammals far from good eating—more bone and horn than flesh. Similarly the mouse-like spine-bearers would make a very objectionable mouthful. And those other mouse-like primitives that developed musk-glands (of which the skunk's equipment is the later perfectionment) were thereby made into very unsavory food-morsels.

The tiny shrews of today illustrate the point admirably. They wear little musk-glands on the sides of their

bodies, about a third of the way between elbow and knee, which give forth a musky secretion that hawks and owls and cats and weasels find very objectionable. So the bodies of shrews that were mistaken for mice are commonly left uneaten. That, obviously, is small consolation for the victim. But what does help, for the race, is that the predator that made the mistake is not likely soon to repeat it. He will look twice before pouncing the next time, and if the intended victim proves to be a pointed-nosed mouse, it will be allowed to pass on in safety. Its musk-bearing defense mechanism will have saved its life.

We may fairly suppose, then, that the majority of little creatures that made up the mammalian population of the early day (say, four or five hundred million years ago) were protected either by musk-glands, by spiny coverings, or by scales and bony plates. Their prime defense, of course, must have consisted in their relative invisibility. None of them wore a coat that did not blend well with its habitual background; and all kept under cover as much as possible, creeping amidst ground vegetation, burrowing, diving on occasion (for all could swim if need be). But if by ill chance they were espied by amphibian or reptilian predators, their visible or smellable defense mechanisms advertised them as creatures hardly worth bothering about or distinctly to be let alone.

And that was how it came to pass that the upstart race of haired, milk-giving, warm-blooded midgets survived, and throve, and multiplied, and gave Evolution a chance to work their further advancement. Even at that, it was doubtless a very close shave for a long time. Very likely it was necessary often to give a single animal more than one defense mechanism. This is clearly sug-

gested by the fact that existing Insectivores, pretty close cousins, have some representatives, as the hedgehog, with spines, and others, as the shrews, with the musk-glands. Even where both have been put aside, as no longer needed, by adults, the young may still show the ancestral character—as in case of the tenrec (*Centetes ecaudatus*), an Insectivore of Madagascar, in which the young animal bears a triple row of spines along its back, which it does not discard until the mature dentition is complete.

Incidentally, this particular primitive shows in another way how parlous the times were for the struggling tribe of mammals in the elder day, by retaining something of the primordial prolificness. It has been known to produce 21 young at a birth. This is perhaps the world record of modern times—tho an opossum with 25 teats has been observed. But the pioneer mothers probably counted such a family as that quite the expected thing. For the matter of that, their descendants of the present day that have held closest to the ancestral type—shrews, mice, and allied midgets—are not far behind their forebears. With five, six, or even eight or ten offspring at a birth, and four or five litters a year, they illustrate the meaning of the word "prolific."

And in so doing they prove that life is still a hard game for their race—but also that where there's a will there's a way to overcome the most appalling difficulties, and to keep your pigmy race in being for milliards of generations, while successive populations of giants rise and thrive for a day and pass from the scene forever.

VIII

ESCAPE BY CLIMBING

WHY have certain groups of animals been taught to climb trees, while other groups, sometimes closely related, never leave the ground? An interesting question, if you stop to think of it.

The famous climbers include not merely the true squirrels, which are world-wide in distribution (Australian region and Madagascar alone excepted), but flying lemurs, true lemurs, marmosets, monkeys, apes, and anthropoids; together with sloths, opossums, raccoons, tree porcupines, bears, and sundry others that one thinks of as in somewhat different categories—either because of their inactivity or because they represent families that are not exclusively or even predominantly arboreal in habit.

Of course the list would be by no means complete without the inclusion of a group of predatory creatures that go into the trees in quest of their prey—fishers, martens, lynxes, pumas, jaguars, and the like. We shall not quite overlook these predators. But our chief concern is with the smaller climbers that have developed the arboreal habit partly because they could find food in the form of fruit, nuts, buds, and the like; but chiefly because by scampering up the trunk of a tree they can escape enemies that would readily capture them had they remained on the ground.

Otherwise stated, we are concerned with the habit of tree-climbing as a defense method, and the modifications

TOWARD BIPEDISM: BEARS AND ORANGS

of body and limb that have been brought about to meet the needs of the arboreal life—such modifications being, in effect, defense mechanisms no less truly than the defensive equipments of more spectacular character previously investigated. No active tree-climber has an equipment like that of the skunk, or a bony carapace like that of the armadillo. American porcupines do, indeed, climb trees, but primarily to secure food by gnawing tender bark, rather than to escape enemies. The Old World porcupines and hedgehogs do not climb trees at all. In general it may be said that the agile tree-climbers have no other notable defense mechanism than the members that give them ability to climb.

Chief of these members are their hand-like feet. In case of the squirrels they are essentially four-toed feet, tho there is a rudimentary thumb. But no one who has seen a squirrel handle a nut needs to be told how hand-like its *manus* is. The hind feet have long, flexible toes, supplemented by claws curved at just the right arc for clutching either the flat bark of a tree-trunk or the contour of a slender branch. The opossums have five toes, and the hind foot has an opposable thumb that makes it very hand-like. The raccoon is famed for the hand-like use it makes of its feet. Its habit of holding a morsel of food in hand and washing it daintily before eating is a human-like trait that is peculiarly appealing—tho obviously this has nothing directly to do with climbing. The raccoon, indeed, gets most of its food by foraging on the ground, preferably along streams, where frogs, crabs, worms, shellfish, and young animals or birds of any kind are accounted suitable for washing and eating, along with almost any vegetables or fruits that are at all edible.

Of the entire group of climbers in our Connecticut woodland, no other has greater interest for us than the

seldom-seen flying squirrel. This beautiful little creature differs from the true or typical squirrels in having adopted a second defense method, in addition to climbing—the nocturnal habit. In addition to that, it has developed the loose skin at either side of its torso into folds that flatten out when the animal's legs are extended sidewise, to form, with the flattened body itself and the wide flat tail, an effective parachute.

The result is that the little climber is able to launch itself into the air, from a branch or tree trunk, and "volplane" down and out, at a wide departure from the perpendicular. To some extent it can control the direction of the sloping descent by action of body or tail. And when near the tree trunk at which it is aiming, it shifts the angle of its entire body, so as to bring it almost at a right angle to the line of descent, and thus is able to increase the air-resistance, and sweep upward in a graceful curve that lands it, head upward, light as a snowflake, against the bark.

By scampering up the trunk, to regain elevation, the little glider can repeat the process, and so can pass on from one tree to another, as far as it cares to go, even where the trunks are separated by many yards, and where perhaps the boughs do not at all interlace—without ever coming near the ground. This is not true flying, but it is directional gliding that accomplishes progression through a woodland in a manner that no other American animal can imitate. To be able thus safely to progress, without touching the ground where such predators as foxes, raccoons, skunks, and weasels would give it eager reception, is the determining factor between prosperity and extinction in many regions, for a creature that has no great speed of foot and no other semblance of defense.

This unique capacity, combined with the nocturnal habit, has enabled the tribe of flying squirrels to thrive and spread through the long generations, till its range includes the best part of the northern hemisphere. Slightly remoter cousins (of the allied genus *Pteromys*), diversified into a dozen species, abound in the Oriental region of southeastern Asia. The same region has a creature of strangely similar habit that is much more distantly related—the "flying lemur" (*Galeopithecus volans*), which is not a true lemur, nor indeed a typical representative of any group, but a law unto itself, with closest affinities, perhaps, with the Insectivores. It is distinctly flying-squirrel-like in appearance, but as big as a cat. The folds of skin that form its parachute are very wide and extend not merely between the legs, but also connect the hind limbs with the tail and the front limbs with the cheeks. The gliding "flight" of this creature is more spectacular than that of the flying squirrels only because of the size of the "lemur." The manner and effect of the volplaning are precisely the same for all of these gliders, with pardonable exaggeration called "fliers."

Other notable groups of climbers, including the marmosets and monkeys of Central America, have hands and feet with grasping capacity exceeding that even of the raccoon, and some of them are provided also with a prehensile tail even more mobile and effective as a grasping organ than the tail of the opossum. That these creatures mostly could not maintain existence in the tropical jungles were it not for their arboreal proficiency goes without saying. In them, the efficacy of climbing as a method of defense finds its most spectacular demonstration. There are few finer examples of the power of Evolution to adapt organs to particular needs.

IX

BURROWING FOR SAFETY

If you put your hand up to your shoulder and move your fingers toward your neck, you will feel a well-developed bone of double curve, joining the humerus and the sternum, which you are accustomed to call a collar bone. You may be interested to know that its presence gives clear testimony to some of your ancestral antecedents. It shows that your forebears, somewhat remote, were inveterate diggers or habitual climbers—perhaps both, but certainly one or the other.

The reason you may be sure of this is that of all the mammalian clans, only the diggers, the climbers, and the fliers kept their collar bones in good working order, while many clans practically abandoned them altogether. And since you will readily admit the high improbability that your ancestors were bats, it follows that they must have been people that either dug their homes underground or else climbed into the trees for safe living. The collar bone by itself, casually examined, does not perhaps very clearly decide between these alternative genealogies, and for the moment we need not look farther into that aspect of the clavicle question.

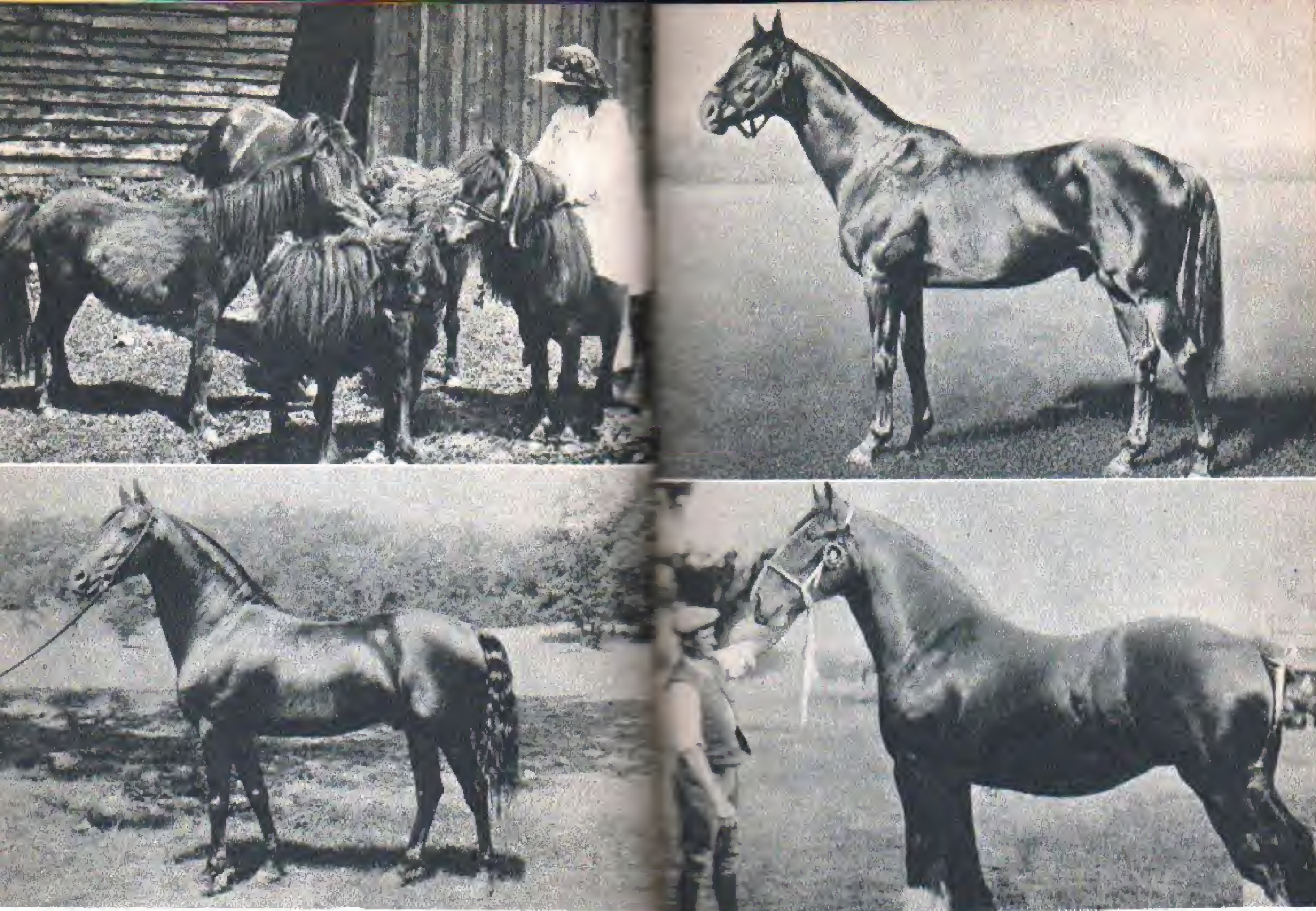
What interests us at the moment is that the abandonment of the clavicle by entire groups of mammals—the Ungulates, or hoofed creatures, for example—indicates that this bone joining shoulder and sternum may be worse than useless for animals that use their fore limbs almost exclusively for locomotion. A horse or deer, jump-

ing, might quite probably break its clavicle—if it had one—on landing. Evolution found that out long ago, and discarded clavicles for creatures that were beginning to specialize in running and jumping. But, on the other hand, the bone completing the pectoral arch at the front might be useful to stabilize the shoulder when the arm came to be used prominently for clutching in various directions, as in climbing or digging.

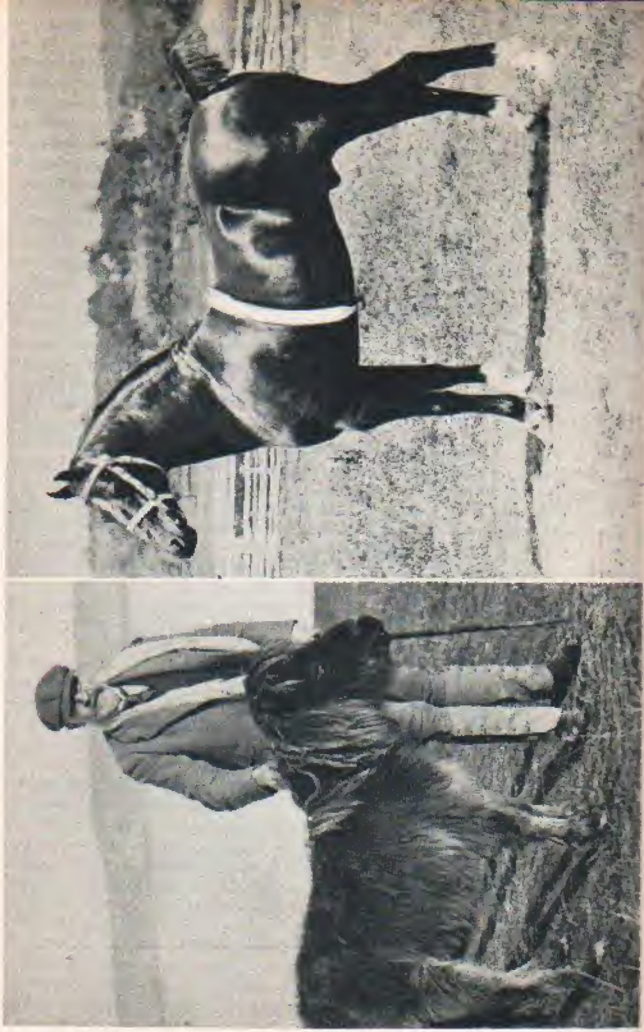
A few million years of experimenting proved the case, and the really expert climbers and diggers all wear well-developed clavicles to this day. Our present concern is with the digging branch of the collar-bone fraternity. In particular with the numerous members of the clan that did not content themselves with merely digging into anthills or grubbing for worms, but bored right down and became genuine cave-dwellers, depending chiefly, or almost exclusively, on their subterranean sanctuaries for safety from predacious enemies.

We have made casual acquaintance with some members of this clan in earlier chapters. We heard something about the woodchuck, a famous digger, tho by no means so closely confined to his underground dwelling as, for example, his sharp-nosed confrère the mole. It may be added that various of the mice and shrews of our acquaintance are also very creditable diggers, with collar-bone-emblems to show full standing in the union. But I think we have not hitherto mentioned, or at most quite casually, a notable member of the clan called the pocket gopher. It is high time to remedy that oversight.

The pocket gopher is a rodent of most ancient lineage. His ancestors have been equipped for championship performance in the line of tunnel-digging for untold generations. Since the Miocene at least, and perhaps a good deal longer, they have worn the great claws, backed by



EQUINE VARIATION UNDER DOMESTICATION



EVOLUTION IN EVIDENCE

bulldog form and strength, that make them sole competitors of the mole, among animals at all of their size, for supremacy in the craft of burrowing. They have spread all over North America, as far north as so uncompromising a burrower could be expected to go. The rocky hills of our New England naturally do not appeal to them, but you may find them in Alabama and Florida; and from the Mississippi Valley on to the Pacific coast they are seldom missing from any terrain that affords even moderately good digging facilities.

Being creatures that almost never travel above ground, they are naturally restricted in individual habitat. This of course leads to close inbreeding in localized colonies, and the tendency to fix and accentuate variations of color and form that arise in response to varied environments. So we find darker coats—sometimes almost black—in fashion in some regions, and coats pale as desert sand in others. That such responsive changes occur in creatures that spend practically their whole time underground, shows that mere sunlight is not the only factor, if indeed it is the chief one, in "bleaching" animal jackets in desert regions, as is sometimes assumed. All told there are upward of a hundred variant forms of the pouched rats sufficiently modified to be given rank of species or subspecies.

But there is no member of the entire coterie that you could ever mistake for anything but a pocket gopher. The squat, bulldog form; the big head with tiny eyes and big teeth that protrude aggressively; and the great digging claws of the front feet are unmistakable. On closer inspection, the fur-lined cheek pouches are revealed as a character in itself distinctive. No other American mammal except members of the family of pocket mice and kangaroo rats has a food pouch that

is fur-lined and opens on the outside of the cheeks. The cheek pouches of the chipmunk and its allies open inside the mouth.

As a boy out in Iowa, I knew the pocket gopher well. On one or two occasions I had the luck to surprize one of the burrowers a little distance from its doorway, above ground, foraging, with cheek pouches distended. But that was a rare experience. As a rule we never saw a gopher unless we dug into one of the many piles of dirt that mark the openings of his long-wandering burrow, and set a trap there. The owner of the burrow was sure to resent the invasion, for it is his rule to keep all doorways covered with piles of dirt—finely pulverized earth making a "gopher mound" that is as unmistakably unique as its builder.

This is not such a formless heap as the woodchuck dumps at the entrance to its burrow, but a neatly symmetrical mound perhaps two feet across and eight or ten inches high, somewhat like an antheap. As a rule it is an unbroken convexity, with no sign of entrance, and until you investigate you would never suspect its origin. But if you dig carefully, you will find a round hole, plugged with earth for several inches below the surface, leading down from its center. Below that, you will see an open hole, or tunnel, leading more or less straight down as a rule for some inches, to join a horizontal tunnel that is part of the tortuous main runway.

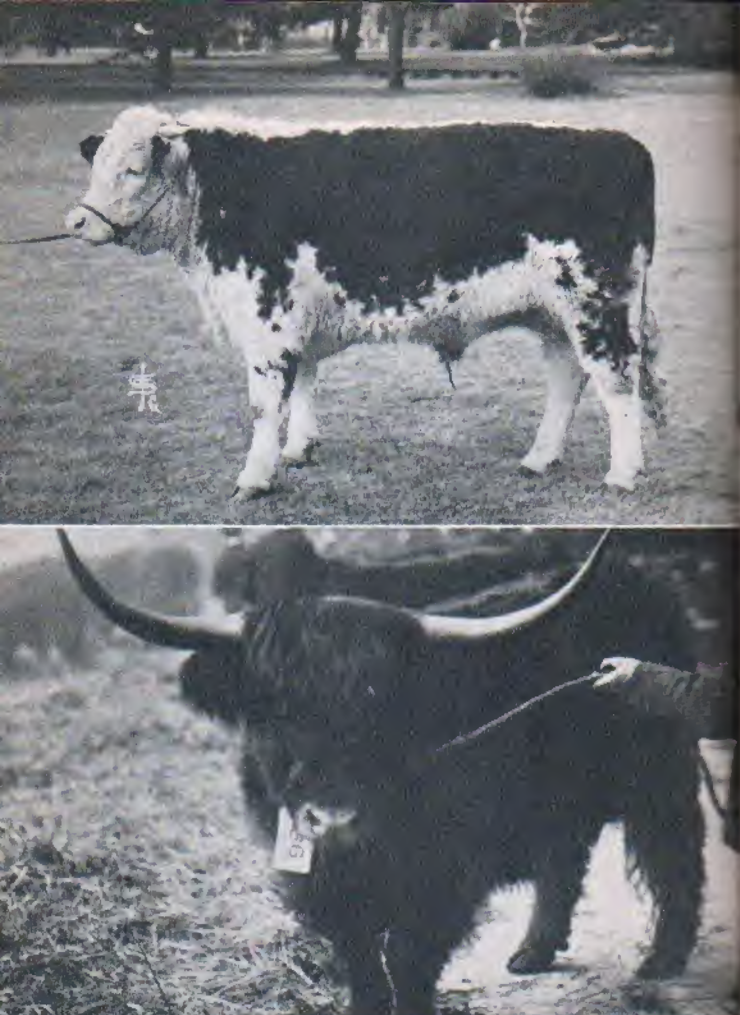
Then you understand that the visible mound represents dirt clawed and chiseled in making the tunnel, and brought to the surface (not in the cheek pouches, but by pushing it along with chest and feet) simply to get it out of the way. In this regard the gopher is a much neater workman than the mole, which bores through the earth by brute force, keeping near the surface when

possible, and thereby mutilating lawns and gardens, and producing at best a tunnel of dubious permanency. The gopher, excavating with tooth and claw, goes habitually deeper, leaving no trace except the telltale mounds at the surface. It can tunnel readily through soils too hard for the mole to penetrate. And its tunnel, once completed, is a fairly permanent runway and abiding place.

Most lawn-makers and gardeners would agree that an occasional earth-mound is less objectionable than the long-drawn-out hummocking that tells of the mole's presence. But the score is perhaps more than evened by the fact that the mole is engaged solely in the pursuit of worms and insects, while the gopher is foraging for roots and tubers; eating his fill of potatoes, and perhaps storing away a bushel or two for the winter; conceivably even gnawing at the roots of fruit trees, to their ultimate destruction.

On the whole, then, not so very good a neighbor is this digger with the fur-lined cheek pouches. Yet certainly one of the most interesting of mammals, so long as he remained on (or rather beneath the surface of) the open prairie where my boyhood acquaintance with him began. After all, tho, leaving the impression of a solitary, morose egoist, utterly lacking in social spirit. Different indeed from that other typically American burrower, a not very distant relative, and not altogether unlike in general appearance, but deservedly so much more famous—the prairie dog. Different also, for that matter, from two other species of burrowers that were abundant on the same Iowa prairies where we found the pouched rats, and which were known to us also as "gophers," tho not given that title by the classifiers.

The animals in question were sprightly, active creatures found only in the open country, but there to be

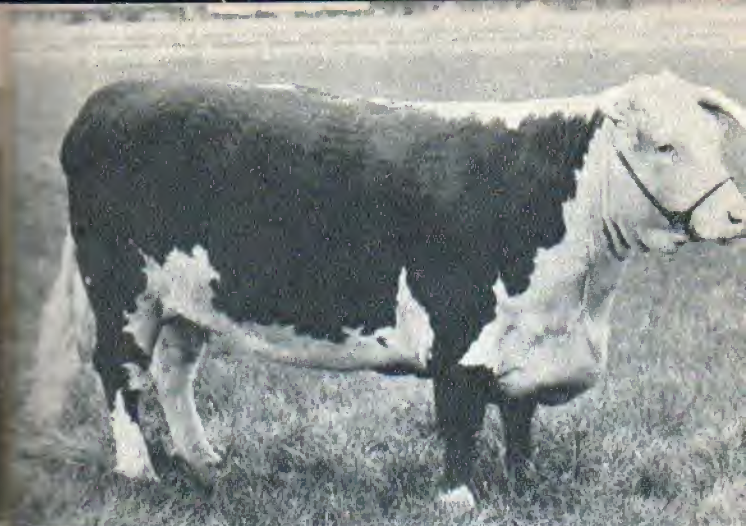


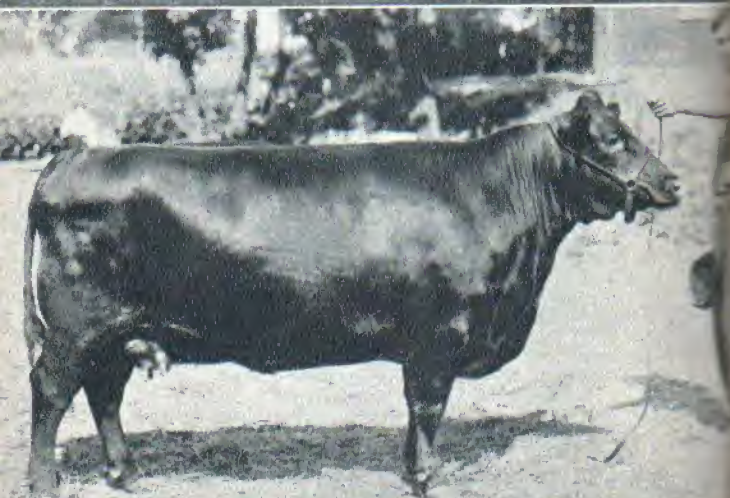
SELECTIVE BREEDING

seen scurrying in almost any direction, seeking their burrows if disturbed, but usually standing upright at the doorway, like little posts as seen from a distance, before diving to subterranean realms of safety. Even a boy knew them for different species, or kinds, of animals. One was not unlike a smallish gray squirrel that had lost its bushy tail. The other was still smaller, not even so big as a red squirrel; in fact, not much bigger than a chipmunk, of which animal it reminded one further because it wore a striped coat—a coat more finely striped than the chipmunk's if you came near enough to see, and with rows of pale dots alternating with the unbroken stripes on the dark background. These animals were known to us as the "gray gopher" and the "streaked gopher," respectively. One never heard them called anything else by anyone.

I learned presently from books (treasured volumes of Audubon and Bachman's *Biography of American Mammals,* which came temporarily into my possession) that these comely haunters of the open are true squirrels in spite of what seemed their unsquirrel-like habitat and habits. They are distinguished, appropriately enough, however, as "ground squirrels," or more technically as Spermophiles. About eighty species and subspecies are named by the modern classifier. They are closely related to the ground squirrels, or true Spermophiles, of Asia.

Another notable group of burrowers are the chipmunks. They number 57 named varieties (suggesting a famous brand of pickles), all bearing the striped insignia of their former genus (now split into two genera). As compared with some of their confrères they are not remarkable diggers (tho they are true squirrels), since they are likely to find lodging places under stone walls and in natural crevices—tho they mostly go deeper to





CREATIVE DEVELOPMENT

find winter quarters in which to hibernate. Unlike the tree squirrels, they are listed among winter sleepers. But I have known one to come out in mid-February, which with us in Connecticut is midwinter, to forage about in snow for a few hours; afterward going back to complete its six-month nap. I never knew a chipmunk out in Iowa to make such a venture as that, however. And as to the ground squirrels, they were deep in their burrows, far below the frost level, coiled in inanimate balls, and to all appearances dead.

By way of contrast it may be noted that the mole and the pocket gopher are believed not to hibernate. But they naturally do no plowing near the surface in a region where the ground freezes solid to the depth of several feet. Presumably the mole finds worms and grubs available in the unfrozen depths. The gopher stores vegetable matter, including sometimes potatoes by the half-bushel, in subterranean vaults of his own construction. The chipmunk stores seeds and nuts, for occasional snacks or for early spring consumption. But not such extensive hoards as those of his cousins, the tree squirrels, who are not hibernators, and would fare ill if obliged to subsist on winter buds and the sapless bark of trees—tho these foods round out their dietary.

The prairie dogs, living in vast colonies, could not possibly find food supplies to store for the winter. One marvels that they find enough to eat in summer, in the semi-desert or full-desert regions they inhabit. Bailey tells of a prairie-dog "town" 250 miles long and 100 miles wide, practically continuous, and estimated to contain 400,000,000 inhabitants. That appears to be carrying companionableness to the extreme limit. The population must be kept within bounds (if you can call that keeping within bounds) largely by starvation, tho hawks,

owls, coyotes, black-footed ferrets, badgers and rattlesnakes do their share.

The fable about the alleged harmonious life of prairie dogs, burrowing owls, and rattlesnakes has been so often repeated that it can hardly be ignored, tho it would hardly otherwise merit mention even for denial. Carnivorous creatures and their natural food do not lie down together unless one encompasses the other. Doubtless that happens often enough, and rattlesnakes may well be supposed to have a penchant for young prairie dogs.

Against such an attack the prairie dogs have no defense. But we are told on what seems good authority that the outraged parents have been known to exact just retribution by digging dirt into the mouth of the burrow, and closing it so effectively that the invader is entombed beyond respite. It is even said that many of the neighboring families of prairie dogs eagerly lend a hand at the digging, that the burrow entrance may be sealed expeditiously and securely before the snake can return from the depths.

The story seems not implausible, for the one time when wild creatures, mammal or bird, are habitually seen to cooperate is when a predacious common enemy appears. The prairie dog is not credited with inordinate intelligence, but so elemental an act of defense as this may well be within its powers; and gregarious life tends to develop capacity for community action.

X

THE MIGRATIONS OF MAMMALS

IN an early chapter some population statistics were presented which force us to conclude that any normal race of mammals has potentialities of increase of population that would enable it, if unopposed, to produce a membership competent to people the entire globe in a comparatively brief span of time—even as time is reckoned in human affairs. It may also be assumed that every species has enough adaptability to adjust itself to gradually changing conditions of climate as its successive generations, in spreading, encounter them.

In other words, short of coming to some absolutely impassable barrier, like an ocean or a mountain range or a veritable desert, any prosperous species, given time enough, would extend its habitat to the entire land surface of the globe. That no species ever quite attains such cosmopolitanism (tho many come very close to it), is because of the resistance offered by environmental conditions—either from animal races already in possession, or physical conditions too disadvantageous to be overcome by the particular species in question. As to the latter point, a tangible illustration is furnished by any gigantic animal of tropical habitat encountering the sparse vegetation of temperate climates. The vegetation may suffice admirably for small animals, yet be inadequate for the big one.

It is obvious that no degree of luxuriance of vegetable growth could suffice to meet the needs of the popula-

tion of even a single species, were that species to be allowed to breed to the full extent of its normal potential of fecundity. Leaving the great tropical animals, like the elephant—which may require a hundred or two hundred pounds of food every day—consider the possibilities of food-consumption of a colony of meadow mice, if unchecked. Each individual requires only a few blades of grass and rootlets per day. But if normal increase were permitted, a very short period would elapse before there would be a mouse to every blade of grass.

It happens, now and again, that an animal—and in particular a meadow-mouse or one of the kindred species—does find environmental conditions favorable enough, for a few years at a stretch, not indeed for absolutely unrestricted increase, but for something so nearly approaching it that the little creatures do become almost as abundant as blades of grass in a considerable territory. And then, obviously, something out of the ordinary must happen in the meadow-mouse body politic.

The particular kind of mouse that has had this experience most frequently within historic times (or at least the one most frequently observed under such conditions) is the cunning little chub-faced beastlet called the lemming, an inhabitant of Scandinavia and of the northern part of North America, including Alaska. This little rodent has achieved a unique place in historical literature, precisely because of its capacity to achieve, once in a human generation or so, a "biotic survival" ratio that brings its population close to the packed-sardine standard over considerable territories.

The lemmings that a few years before were only occasionally seen to scurry through the grass, like any other cowering mice, on one such occasion became a devastating horde, taking toll of every reachable kind

SHEEP THAT ARE DIFFERENT

of vegetation. And this horde, threatened with starvation, was soon found to be moving *en masse* in a given direction. It became then an army, sweeping on regardless of obstacles, devouring every eatable thing it encountered—a horde of such unbelievable numbers that no manner of opposition from man or predacious beast and bird could for a time cope with it.

Of course the ranks were finally decimated, and the horde melted gradually away. But the ranks were constantly recruited by the birth of new generations, and the survivors kept on and on—always in the same direction. The normal impulse to spread in all directions had been supplanted by an urge to mass movement in one direction. A veritable emigration was in progress, from which there would be no returning. And if any remnant of the horde survived to reach the shore of the ocean, the emigrants did not hesitate to plunge into the water, and swim bravely on—to destruction. Mere rivers and small lakes had been crossed; why balk at an ocean?

A few lemmings always remain in the old territories—cripples or stragglers or deserters, or what you will, to repeople the land. But for a good many years after such a "migration" the species is not abundant in its ancient habitat. And a good many more years may elapse before the natural checks on increase of lemming population again slacken sufficiently to permit adequate preparation for a new hejira.

Other animals, including the gray squirrel, have been known to emigrate in hordes, in a manner altogether similar. Such manifestations are, however, exceptional. In general, small animals seem to lack the instinct for such mass movement. If their numbers increase too rapidly for the food supply, they starve. Dead shrews are sometimes found in large numbers in a meadow where

they were seen but seldom when alive. It is surmised that they have starved, but of course it is always possible that some epidemic disease may have been the cause of the disaster.

Such one-way "migrations" as these mass movements of lemming and squirrel are not at all comparable to the seasonal two-way migrations of birds, which seek breeding places in the north, and retire to warmer climates for the winter. True migrations comparable to those of the bird are accomplished, however, by a few mammals, including the bats (of some species), bison, caribou and —very notably—the sea-lions and fur seals. The migrations of the fur seals to and from the Pribilof Islands of Alaska, where they breed, are among the most spectacular of animal achievements. The "sense of direction" that enables the animals to go unfailingly to their island homes across thousands of miles of the Pacific Ocean is one of the marvels and mysteries of animal "instinct."

The seals achieve almost entire immunity from enemies—except man—on their island breeding ground. But killer whales take toll of their smaller members during migrations, and there are doubtless other hazards incident to long voyaging. So the increase is kept within bounds, even without man's interference. Yet the capacity for increase, even of an animal that has but one offspring at a birth, is shown by the rapid rehabilitation of the Pribilof herd, when given reasonable protection, after its near-extermination by the depredations of fur-hunters of half a century ago. The fact that Evolution has brought the seal to the one-offspring limit of birth control in itself evidences the relative safety of the species from predacious enemies, and from hazards of life in general, under natural conditions.

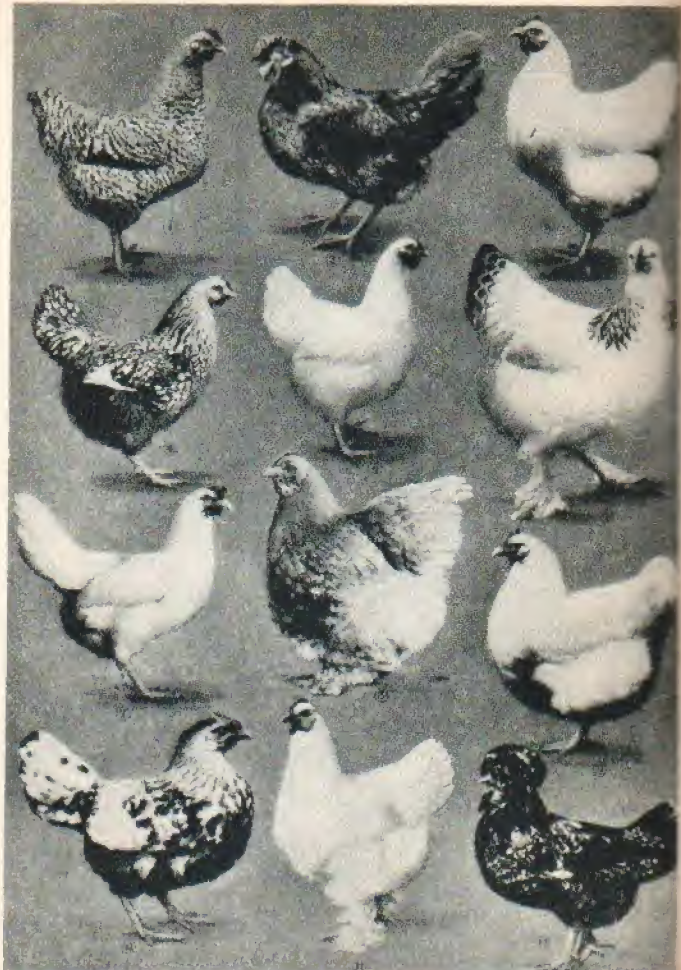
It is interesting to note that the seals, like the whales,

ANCESTRAL AND MODERN CATS

retain their diurnal habit that must have been natural for mammals in general until so many of them were forced to seek protection in darkness against the multitudes of sharp eyes of predators that sought their lives. That the mammalian predators also became nocturnal in habit was a natural sequel—since they must adapt themselves to the habits of their intended victims. Seals are predators, but their victims are mainly fishes. And as they seek their prey under water, they must naturally be guided chiefly by sight. So good eyes are at a premium, and full daylight gives none too much light at the depths to which they must often descend.

Even the hair seals, which have their breeding colonies on floating ice in the Bay of St. Lawrence, and which gnaw or break holes in the ice when they leave their young to go fishing, and return by the same route (exciting wonderment that they can come back to their own offspring with certainty under such unpropitious circumstances), probably depend on sight mainly; tho the sense of smell may be the final test in discriminating between hundreds of pups which, to any but the maternal eye, seem absolutely identical.

Animals of the land, on the other hand, and in particular those of nocturnal habit, have mostly developed the sense of smell as a better substitute for eyes. Many of them have developed scent-glands, variously located (on the sides of the shrew, the rump of the peccary, the legs of deer, between the toes of sheep) to guide members of their own species and enable them to keep track of one another. And the sense of smell, for detection of both friends and enemies, becomes highly sensitized, as a defense mechanism for the vegetarian tribes, and an aid to locating and following their prey for the Carnivores.



HENS TO SUIT ALL TASTES

The ears, naturally, are correspondingly developed. In particular, the animals that have no direct method of defense, other than capacity for speedy flight, require good ears—and have been provided with them, through evolutionary adaptation. The rabbits and hares and deer furnish extreme instances. On the other hand, whales and hair seals have no external ears at all, and the external ears of such burrowers as the mole are also minimized or discarded. But it is significant that the sea-lions and fur seals, which have occasion to keep together during their long migrations, retain external ears, and presumably depend much more on the sense of hearing than the more sedentary hair seals are required to do.

A creature that migrates through waters frequented by killer whales—the "wolves of the sea"—requires all senses in full operation; in particular since the voyaging is not interrupted for the night. Even if it were, the hazard would not be gone, since there is no resting place but the water. So nose and ears must take the place of eyes. And after the journey is over, the mother seals must constantly return to the water, despite its perils, and make long tours in quest of food to supply the needs of their offspring. The male, it may be added, escapes this hazard, since he remains on the island uninterruptedly for a term of weeks, to guard his harem from young Lotharios that are always lurking in the background. Perhaps to appease the pangs of hunger—and literally cure the hunger pains incident to contraction of the musculature of the stomach in fasting—the male seals are known to swallow largish stones.

This curious concomitant of the highly specialized domestic economy of the seals has excited much speculation. That the master of a harem should be able to go without food for such periods is itself remarkable, tho

not without precedent. The salmon, migrating up rivers to its breeding haunt, similarly abstains from food. But the salmon's heroic migration is its last gesture in life, whereas the seal seems to thrive on the stone diet, and may live to complete many migrations. Indeed, it is only after some years of experience that a male seal attains size and strength that enable him to command a harem. The fact that only the very strong and brave attain the fair is an illustration of Evolution's method of providing for the maintenance of strength and virility in the species, through heredity. From the loins of no weakling must spring the race that can survive only by making semi-annual migrations some thousands of miles in extent, through perilous waters.

NOT BRED FOR BEAUTY

XI

THE GRIP OF HEREDITY

THE basic law of heredity is simply this: Every living creature *tends* to transmit to its offspring every physical trait of its own organism. For the present purpose we need not extend, qualify, nor even interpret that law. Let the words be accepted exactly at face value. They constitute a slightly qualified paraphrase of the ancient statement: Like begets like.

Here is, for example, a colony of deer mice. Let us view its members in the light of what we learned in an earlier chapter about the oscillatory emigrations of prosperous races in general. Our deer mice are prolific. Despite their hosts of enemies, they tend to increase at a rather alarming geometrical ratio. When they do prosper, they prosper enormously. With new broods appearing and coming to maturity in terms of weeks, they must perennially send emigrants beyond the confines of our colony, and on and on, in the course of the decades and centuries, to the utmost confines of the far-spread habitat. And counter-waves, of course, are sweeping in the opposite direction—in all directions.

The net result is that if the roster of ancestors of any deer mouse of our colony or any other colony of the entire population, could be called for, say, the thousandth past generation, its millions of individuals would include residents of every square rod of habitable territory of the entire domain, from Maine to Nebraska and from Ontario to Virginia—and far beyond.

And every one of these millions of ancestors of that remote generation will have tended to transmit to each and every one of its present-day descendants every particularity of its own organism. If the first law of heredity holds, it cannot have been otherwise.

An alarming thought? It would be, indeed, did we not recall that, by hypothesis, each one of these millions of ancestral deer mice was (in the larger view) precisely like every other one. The *essential* traits that each one tended to transmit were exactly the same essential traits that every other member of the company tended to transmit. So there was harmony of effort, instead of discord. Each salient trait, as transmitted, was fortified a millionfold. There was no conceivability of failure, where all influences united to the same end. There was no possibility that the offspring of the thousandth generation should be other than a deer mouse like each and all the myriad deer mice that were its great-great (to the thousandth repetition)-grandparents.

That is why the deer mouse of our Connecticut colony is identical, as to salient features of size, color, teeth, skeleton, and habit, with the deer mouse of Iowa and of every acre of habitable territory between, and for some hundreds of miles to north and south. And of course we have used the deer mouse only for purpose of explicit illustration. The same reasoning, as to essentials, applies as well to practically all the other mammals of our latitude—from meadow mice and shrews to rabbit and raccoon and fox and white-tailed deer. Indeed, the same principle of heredity applies—it is perhaps needless to say—to every animate creature. That like *tends* to beget like is a formula that is all-compassing. Were this basic principle to be abrogated for a single generation, there would be chaos in the organic world.

XII

THE POWER OF ENVIRONMENT

LET us hold to the theme of white-footed mice, or deer mice, a little longer. We have viewed one type of these little creatures, inhabiting a territory extending across the northern part of the United States, from the Atlantic to the region of the Great Plains. It was intimated that other types of closely allied character were to be found in the regions beyond, in every landward direction. It remains to be said that these allied types of deer mice, occupying all suitable localities onward to the Pacific and from the Arctic Circle to the tropical zone of southern Mexico, are so similar in general appearance and habit that a casual observer would at once rank them all as "white-footed" mice, and feel very sure that they must be rather closely related.

On the other hand, a technical observer, while agreeing that all the deer mice from the various regions are genetically related (of common origin), would point out differences of size, of color, and of anatomical construction (skull, teeth) to justify the separation of the clan as a whole into something like one hundred and fifty named subspecies, grouped into upward of forty full species. He would speak of "geographical races," and would easily convince you that specimens of deer mice from the Arizona desert, for example, are quite different in appearance from those collected in Florida or in Oregon.

Indeed, he could produce specimens collected within

the same few miles of territory showing corresponding discrepancies, telling you that one form had inhabited the lowland and the other the higher region of a mountain slope.

He would present maps showing that certain forms of deer mice are confined to isolated mountain peaks or high plateaus in Texas or New Mexico or Southern California; that another form is found only in Florida; that there are several distinct forms each occupying only a single island off the California coast.

And the lesson he would thus illustrate and emphasize is that climate puts its mark on an animal species unequivocally and indelibly.

Climate is defined essentially in terms of temperature and moisture. A territory in which the conditions of temperature and moisture are fairly uniform will have a relatively uniform animal population. That is why we find the deer mice and most other mammals closely similar or identical in southern New England and in Ohio and Michigan and Iowa.

But when we shift beyond Iowa to the plains of Nebraska, the climate changes. To west and south, beyond that, still greater changes occur. We encounter the region of the "Great American Desert," and then the Rocky Mountain range; and beyond that another arid region, and more mountains; and then the Mojave Desert and the Coast Range bordering the coastal region In a word, a kaleidoscope of changing topographies and climates.

Dr. Edward A. Mearns points out that a line drawn from either the Gulf of Mexico at the Mexican border or the Pacific border-line to the summit of the San Francisco Mountains in central Arizona crosses the same "life areas" that are bisected "by a line drawn from the equator to the north pole through the continent of North America."

Thus if you follow the Mexican border of the United States from Gulf to Pacific, you encounter an amazing variety of topographies and climates. And each region stamps certain peculiarities upon every species of animal inhabiting it. In general terms, deserts produce pallid forms, and moist regions dark forms. And a desert at high altitude, like that of central Texas, has different effects from a sea level (or even sub-sea level) desert like that of southern California.

Dr. Mearns, who made a classic investigation of the mammals of the Mexican boundary, gives this illuminative summary: "It is certain that no mammal is precisely the same in any two of the five principal tracts [between Gulf and Pacific], altho the degree of variation—which is by no means confined to differences of color, but extends to form, proportion, and size—varies in different groups and species. In many cases species pass through a regular intergradation, on the borderland, in passing from one tract to the next."

Further details as to color variations, applicable more or less to any species or form having wide range, are worth citing:

"Pallid forms came always from the two deserts, and dark forms from the elevated tract which separates them and from the coastal regions bordering the Gulf of Mexico and the Pacific Ocean. Again, the pallid forms from the high Eastern Desert Tract differed from the pallid races of the same species in the low Western Desert Tract, and the darker forms from the Elevated Central Tract differed appreciably from those of the Middle Texas Tract and the Pacific Coast Tract."

All this of course is only an illustration, from a local-

SELECTIVELY BRED FOR DIFFERENT UTILITIES

ized region, of the general truth that climate and soil put their stamp on animals just as they do on vegetable life. This principle, long recognized, has led to the allotment of "life zones" that supposedly delimit the bounds of the normal habitats of various species of animals. We shall have occasion to examine the problem of life zones more in detail in another connection. Our quest of the moment is an explanation of the puzzling relation between climatic conditions and animal variation just illustrated.

Explicitly stated, our problem is this: We found a seemingly valid explanation of the uniformity of life of deer mice from New England to Nebraska and from Canada to Virginia, in the thesis of perennial intermingling of successive generations of individuals, and the operation of the basic law of heredity, according to which every individual tends to transmit its characteristics to its offspring. But how are these principles to explain the divergence of forms? How explain the alterations that mark the deer mouse of Georgia and Alabama as a different variety from that of Virginia; and the Florida deer mouse as still more divergent, ranking as another species?

In a word, how are the facts of geographical distinction of races consonant with the principles of perennial intermingling and the operation of the law that like begets like?

A part answer is found in the fact that the diverse geographical races are not sharply shut off one from another, unless located on islands. On the contrary, "the various subspecies frequently merge insensibly into one another, so that it may be difficult to assign individual specimens if they come from such an area of intergradation" (Anthony). This is equivalent to saying that emigration back and forth does take place, with attendant interbreeding, through which the divergent traits are blended—precisely as a population of mulattoes, quadroons, and octoroons might be found in territory intermediate between regions occupied respectively by whites and negroes, which are geographical races of the human species.

It remains only to explain the development of the geographical races themselves. Here again we have to do with one of the great basic factors of organic existence. The elemental fact is that every living creature draws its sustenance directly or indirectly from the vegetable kingdom, and that plant life extracts its nourishment from the soil. The chemical constitution of the soil is therefore a salient factor in determining the types of vegetation of any region; the other factors being temperature, light, and moisture.

Crudely but cogently stated, every animal organism is an intricate chemical compound of unique character. As a concrete illustration, a mother and her new-born offspring may have different types of blood that cannot safely be intermingled. Broader features of chemical composition are of course shared by animals of a species, even of a genus. Thus it can be shown by chemical tests that the blood serum of every member of the cat family has essential similarities not shared with any other family of animals.

Such tests would show the relationship of the American puma, for example, and the African lion, which have lived in different hemispheres for millions of years. But beyond that, there are more intimate similarities shared by members of the same species (all pumas, for example). But similarity never extends to the point of identity.

Moreover, the same individual may change many elements of its chemical composition from day to day, as blood tests readily prove. This, indeed, is matter of common knowledge; for everyone knows that the "flavor" of edible flesh may be greatly modified by the diet of the animal or bird. Witness the gourmet's avidity for "celery-fed" canvasback duck from the Chesapeake, and for beef from the "corn belt."

It may fairly be assumed, then, that the intimate nature of the organism of any animal will be changed explicitly (even if not always demonstrably) by a change in diet. And it goes without saying that every wild animal necessarily changes its diet when it shifts its habitat from one climatic zone to another. Such shifts, as we have seen, are normally accomplished very slowly, over periods covering many hundreds or thousands of generations. But from the moment the pioneer emigrants enter a new habitat, responsive modifications begin to take place in their organisms.

This is merely another way of saying that the organism in a new environment begins to vary from the ancestral pattern that had been developed in response to the old environment. Certain superficial modifications are readily understood. If the new region is more arid than the old, the excess of sunshine will tend to bleach the hair of the newcomer. If, on the other hand, the new region is more humid, the relative cloudiness and shade will tend to put a premium on darker coloration. The matter of size, too, may quite explicably be influenced by greater or less abundance of food supplies, or by prevalence or paucity of certain chemicals—for example, iodin, which stimulates thyroid activity; or calcium, for bone-making—in the new dietary.

That these modifications should be heritable is an in-

ference that is unavoidable, if we accept the dictum that every organism tends to transmit all its qualities to its offspring. It is, I believe, an absolutely justifiable conclusion. But note, please, that the degree of modification that any individual organism can have experienced is infinitesimal in comparison with the myriad old qualities that make it the organic personality that it was and is.

Only by the cumulative effect of minute modifications added to and constantly sustained by an environment favoring the change, will sufficient alteration have been wrought, *after thousands of generations*, to be appreciable, even to the eye of a trained zoological observer. To the animals themselves, the changes are doubtless much more evident, but even so, they will continue to interbreed, if artificially brought in contact, and thus acknowledge kinship, long after the divergences have become sufficient to justify the human observer in classifying the new form as a distinct species.

For illustration, let us revert to the deer mice, which by partial isolation in widely separated regions—from Labrador to Mexico and from Florida to Alaska—have developed some scores of subspecies in the course of odd tens of thousands of recent generations. Some are upward of nine inches long (Alaska) and some only five inches (Florida); some are almost black above and some bleached to straw-color. But all retain the white feet and vest that are the insignia of their genus; all retain the same general form and manner; all are terrestrial and nocturnal of habit; all are prolific breeders.

As to internal constitution, one description, even in detail as to anatomical and physiological characters, would answer adequately for them all. Even the tooth-formula does not vary by a single item; and the modifica-

tions of skull are so insignificant that no two human taxonomists will agree as to their relative importance.

In a word, the various races of deer mice furnish a superb illustration of the evolutionary process in actual operation. They show us species in the making.

AN UNPREPOSSESSING ANGLER